AGRONOMY SEMINAR
305 DAVENPORT HALL

ОЧВОВЕДЕНИЕ

SOVIET SOIL SCIENCE

6

JUNE 1961

A TRANSLATION
OF POCHVOVEDENIYE

★

AMERICAN INSTITUTE
OF BIOLOGICAL SCIENCES
2000 P STREET, N.W.
WASHINGTON 6, D. C.

SOVIET SOIL SCIENCE

A. P. MAZURAK, *Editor*

Department of Agronomy, University of Nebraska

Patricia Haley
Assistant Editor

American Institute of Biological Sciences

Officers
FRITS W. WENT, *President*
JAMES EBERT, *Vice-President*
F. P. CULLINAN, *Secretary-Treasurer*

Executive Director
HIDEN T. COX

Manager of Publications
FRANCIS C. HARWOOD

Governing Board
GEORGE BEADLE
ALBERT P. BLAIR
DAMON BOYNTON
DAVID E. DAVIS
E. L. DULANEY
WALLACE O. FENN
CLIFFORD GROBSTEIN
A. M. GUHL
FREEMAN HOWLETT
PAUL KRAMER
W. GARDNER LYNN
DOROTHY MATALA
S. E. A. MCCALLAN
V. MCKUSICK
BERNARD S. MEYER
FRED S. ORCUTT
ROGER REID
REED C. ROLLINS
RAY F. SMITH
WILLIAM C. STEERE
JOHN A. STEVENSON
CARL P. SWANSON
KENNETH V. THIMANN
A. C. WALTON
RICHARD G. ZWEIFEL

THE translation and publication of this and other Russian language biological journals and monographs is a project of the American Institute of Biological Sciences. This project is supported by grants from the National Science Foundation. Each publication is a cover-to-cover translation of its Soviet counterpart and the contents are only those of the original authors.

Pochvovedeniye in English translation bears the Soviet issue numbers. The Soviet journal carries no volume numbers. Translation begins with Number 1, the January 1958 issue. It is published in the same number of issues per year as the original Soviet journals: 12 issues.

translated and produced by
ROYER & ROGER, INC.
INTERNATIONAL DIVISION

Subscription Prices:

$40.00 per year, individuals and industrial libraries
20.00 per year, university and non-profit libraries
3.00 additional to each price for foreign orders
4.50 each, single copies

Order from:

American Institute of Biological Sciences
2000 P Street, N.W., Washington 6, D.C.

© 1961 American Institute of Biological Sciences

SOVIET SOIL SCIENCE

A translation of the monthly journal—POCHVOVEDENIYE—
a publication of the V. V. Dokuchayev Institute of Soil Science,
Academy of Sciences, USSR. A journal founded in 1899.

Pochvovedeniye Editorial Board: I. V. Tyurin (editor-in-chief), I. N. Antipov-Karatayev, N. I. Gorbunov, K. P. Gorshenin. A. A. Zavalishin, V. N. Zavaritskii, S. V. Zonn (assistant editor), O. K. Kedrov-Zikhman, V. M. Klechkovskii, V. A. Kovda, M. M. Kononova (assistant editor), Ya. V. Peive, I. I. Sinyagin, A. V. Sokolov

---

No. 6: June 1961 Translation printed: April 1962

CONTENTS

	Page	Russian Page
PRIMARY STAGES OF SOIL FORMATION ON MASSIVE-CRYSTALLINE ROCKS OF THE SMALL HILLS AREA OF NORTHERN KAZAKHSTAN, by M. A. Vinokurov and L. G. Bukharayeva	591	1
DUST STORMS IN SOUTHERN UKRAINE IN THE SPRING OF 1960, by V. A. Kulikov	598	11
CHARACTERISTICS OF THE VERTICAL ZONALITY OF SOILS IN CENTRAL AFRICA, by I. A. Denisov	604	19
PROBLEM OF THE "HYDROPHYSICAL" SOIL CONSTANTS, by A. A. Rode	609	26
EFFECT OF MAGNESIUM FERTILIZERS ON SANDY LOAM SOD-PODZOLIC SOIL, by V. S. Rubanov	620	39
INFLUENCE OF PINE AND BIRCH FORESTS ON THE SOILS OF THE SOUTHERN URALS, by Yu. D. Abaturov	627	47
ORIGIN OF SOILS WITH A WHITISH HORIZON IN THE PLAINS OF THE AMUR REGION, by E. A. Kornblyum and B. A. Zimovets	634	55
FORMS OF ACCUMULATION AND MIGRATION OF SUBSTANCES IN BOG SOILS, by V. N. Yefimov	643	67
SOIL-FORMATION PROCESSES DURING THE INVASION OF SANDS BY PLANTS IN THE NORTHERN DESERTS OF THE CASPIAN REGION, by T. F. Yakubov and R. Ye. Bespalova	651	77
NITRATE SOLONCHAKS OF THE MURGAB OASIS, by V. A. Molodtsov	659	87

METHODS

	Page	Russian Page
EROSION CONTROL PROBLEMS AND RESTORATION OF SOIL PRODUCTIVITY IN THE UNITED STATES, by S. N. Ryzhov	664	93
UNDERSTANDING OF THE TERM "MANTLE CLAY LOAMS", by P. N. Chizhikov	668	97
CAUSES FOR THE FORMATION OF A TEMPORARY WATER TABLE IN FINE CLAY LOAM SOD-PODZOLIC SOILS, by M. F. Podvoyskiy	673	103

Page Russian Page

INFLUENCE OF THE TIME OF SAMPLE WEIGHING ON THE ACCURACY OF SOIL MOISTURE DETERMINATIONS, by M. A. Sabitov 676 105

ACCURACY OF SINGLE SOIL MOISTURE DETERMINATIONS BY THE WEIGHING METHOD, by I. S. Shpak and M. M. Kostyuchenko-Pavlova ... 678 107

CHRONICLE

ZINAIDA YUL'YEVNA SHOKAL'SKAYA 684 112

NIL PETROVICH REMEZOV 686 114

BIBLIOGRAPHY 691 118

RIMARY STAGES OF SOIL FORMATION N MASSIVE-CRYSTALLINE ROCKS F THE SMALL HILLS AREA OF NORTHERN KAZAKHSTAN

A. VINOKUROV and L. G. BUKHARAYEVA, Kazan' Ul'yanov-Lening State University

B. B. Polynov was the first in the history f soil science to approach the solution of ne problem of weathering and soil formation rom a biogeochemical point of view. Using ne method of the combined analysis of rock, oil, and plants, he proved conclusively that ne study of the process of soil formation rom unfertile rock must be started from its rimary stages. Polynov concludes his artile published in 1945, containing the analysis f the first results of studying the primary stages f soil formation on massive-crystalline rocks, y deductions of an individual and general ature (15). They result in the following: 1) ne appearance of the primary stages of soil rmation is due to the action of lithophyllic egetation on massive-crystalline rocks. he following stages of soil formation take lace on material prepared by lithophyllic chens; 2) the action of lichens is expressed n the mechanical destruction of the rock and ne biochemical reworking of its minerals;) there is no isolated mechanical weathering n nature which is not associated with chemial changes, and vice versa. "The existence sterile weathering," writes B. B. Polynov, is doubtful, even in the desert." Later the esults of his investigations were confirmed nd supplemented by the new data obtained by llow workers at the laboratory headed by olynov, Aydinyan (1, 2), Assing (4, 5), obritskaya (6), Glazovskaya (7, 8, 9), Parfenva (13), Troitskiy (18), and Yarilova (19). hus, for instance, Glazovskaya found in ddition to bluish-green algae, bacterial ora and low fungi on the lower side of exliated crusts of granite in the nivation zone the Tyan'-Shan'. She proved experimentally at minerals are being decomposed and new ineral and organo-mineral compounds are eing synthesized under the influence of the tivity of various groups of microorganisms). Consequently, lithophyllic vegetation, cluding lichens, colonize on substrata which e already prepared by microorganisms. The nswer given by Polynov in one of his later ticles to the question of what the action of thophyllic vegetation is in the first states weathering was the following: "1) the echanical destruction of minerals, 2) the sorption of mineral elements, and 3) the rmation of secondary minerals" (16).

Thus, in the final analysis, the action of thophyllic vegetation in the first stages of soil formation leads to the reworking of the substrate prepared by microorganisms and to the creation of conditions for the existence of more highly organized vegetation formations. Below we will give the results of a study of the action of lithophyllic lichens and mosses on granite and quartz sandstone; in addition the authors studied soil having only one sod horizon.

The material for chemical analysis was collected on the small hills of Northern Kazakhstan. The samples were taken from the Dzhelandin hill, located in the Zerendin rayon, and from the Kiselev hill in Chistopol'skiy rayon. Both rayons are located in the Kokchetav Oblast' in the area of the small hills of Kazakhstan. The predominating soils in the region are ordinary chernozems.

The climate of this part of Kazakhstan is sharply continental, characterized by a warm summer and a severe winter with little snow. The mean temperature in January is -17°C and that of July, +20°C. The annual amount of precipitation in mountainous areas is 400 mm. The snow cover persists from the first decade of November to mid-April. The amplitude of the daily temperature variation is very high: the rocks warm up greatly during the day and cool at night. This is one of the causes of the destruction of rocks and of the formation of cracks in them.

The Dzhelandin hill (more precisely, ridge) is a huge chain of hills, a great part of which is covered by a pine forest. It extends from the north to the south-southwest and reaches an elevation of 600 m above sea level in certain places. The Dzhelandin hill consists of medium-grained granite. Numerous granite buttes of a very peculiar shape, often resembling Chinese pagodas, are scattered over its surface. There are many large rocks at the foot of these buttes, while the debris train on their slopes is covered with fine fragments and gravel. The samples were collected on the summits of the hills, where there is no transport of foreign material except for atmospheric dust.

A forest-free granite butte, 15 m in diameter and 50 m high, was selected in the system of the Dzhelandin hills. There is a slightly raised granite slab on its surface which is covered with the foliated lichen Parmelia Sp. of a grayish-green color. Underneath there is a considerable amount of fine earth of a dark color; the fine earths contain lichen residues and small pieces of minerals (Sample 1).

At the edge of the granite slab there is a cleft in the form of a small niche, 4 cm wide and 0.5 m long. Green Ceredoton purpurus moss grows in it. The thickness of the entire layer is 5 cm. Apparently the moss developed on the fine earth which formed under the lichen. The moss cushion is very soft and loose and underlain by a layer of fine earth of a black color; it is damp, friable, and structureless (Sample 2).

Sample 3 was taken from the summit of another granite butte, located in the vicinity of the first. Its diameter is 20 m, and its height 50 m. It also consists of medium-grained granite. Festuca ovina grows in the cracks between individual stone slabs, and in some places single specimens of pinks, wormwood, and campanula are found. All grasses are low and weak. We took sod from the sheep's fescue in a crack 20 cm deep and the fine earth underneath for analysis. The sod is rather hard and peaty; stone fragments and friable fine earth of a sandy color are found between the sheep's fescue stems. The fine earth is underlain by rock which contains cracks.

For comparison we collected samples of another rock — quartz sand from the Kiselev hill. The Kiselev massif is also a chain of hills extending from north to south and reaching a height of 400 m above sea level. There are small birches in certain places in narrow clefts between the blocks, which have adapted themselves to these severe conditions. Grass grows in depressions and clefts, consisting predominantly of Festuca ovina. The surface of the rocks is amply covered with lichen, primarily scaly. Unfortunately we were unable to collect enough fine earth from under it for chemical analysis. We had to limit ourselves to the fine earth from under the Polytrichum piliferum moss and sheep's fescue.

Sample 4 was taken at the top from a funnel-shaped hole 10 cm deep where sheep's fescue grows. Fine earth, riddled with roots, underlies the sheep's fescue sod.

Sample 5 was taken on the eastern slope, 2 m below the summit, from a bare area in the form of a ledge. Polytrichum piliferum moss grows in the cleft (5 cm deep), and individual specimens of pink, Sedum, etc. are found in places. We took sod from the moss and fine earth for analysis. The sod is cinnamon-brown and contains hard rock fragments; the fine earth is brown, friable, and structureless.

Let us begin the description of the results of the investigations from a discussion of the data on the total chemical analysis of granite and fine earth collected under various plants.

As can be seen from Table 1, the loss of fine earth from under the lichen on ignition is considerable; it is even higher for the fine earth from under the moss, while it is low for the fine earth from under the sheep's fescue. Consequently, the fine earth from under the first two plants is characterized by a high content of organic substances. Further, comparison shows that there is less SiO_2 in the fine earth from under the lichen than in the rocks; the same is true for the fine earth under moss. The foregoing fact, according to Polynov, is normal during the first stages of soil formation taking place under eluvial conditions (14). This was also confirmed by certain fellow workers of his laboratory (4, 7, 9, 13), and recently by Targul'yanov (17), Leneuf (12), and Gorbunov and Sun Da-chen (11). As far as aluminum and iron are concerned, there is a certain difference in their content: the fine earth under the lichen does not differ from the rock in the amount of aluminum, while it contains almost twice as much iron; the quantitative ratio between these elements in the fine earth under moss is the reverse, which can be seen clearly from the molecular ratio of SiO_2:Al_2O_3 and SiO_2:Fe_2O_3. The lack of removal of Al_2O_3 and Fe_2O_3 from the fine earth under lichen and moss, and in certain cases their accumulation, must be attributable to the low solubility of these compounds. The calcium, phosphorous a sulfur content in the fine earth under lichen and

Table 1

Total chemical analysis of granite and fine earth

Sample No.	Sample investigated	Ignition loss	In % of ignited sample										
			SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	SO_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{K_2O}$
	Granite	0,67	70,51	16,47	1,55	1,78	0,83	2,55	0,25	0,28	7,2	120,9	43,2
1	Fine earth under the lichen Parmelia	41,00	68,63	16,40	2,89	2,47	0,42	0,36	2,38	1,43	7,1	63,1	292,8
2	Same under the moss Ceredoton purpurus	48,91	67,23	19,28	1,50	3,28	0,53	0,87	2,43	1,29	5,9	120,3	121,6
3	Same under sheep's fescue	6,18	80,71	11,12	1,53	1,08	0,31	0,79	0,92	0,88	12,3	141,3	159,8

Note: Comma represents decimal point.

moss is much higher than in the rock, which is undoubtedly due to their concentration by the vegetation.

A different picture is found for magnesium and potassium. As we know, they are intensely absorbed by vegetation and it would seem that they would accumulate in the fine earth; however, this is not so; the rock contains more of these elements, especially potassium, than the fine earth under lichen and moss. As a result, the molecular ratio of $SiO_2:K_2O$ in the fine earths under lichen and moss widens greatly as compared with that in the rock. The impoverishment of the fine earth in magnesium and potassium occurs not only as a result of their absorption by lithophyllic vegetation, but apparently also as a result of leaching, a fact observed by other investigators (9, 11, 12, 13, 15, 18).

The composition of fine earth under sheep's fescue differs greatly from that under lithophyllic vegetation. First of all, attention is drawn to the higher content in it of silica, as compared to the rock, which is almost 81%. This can be explained by the decrease in the content of aluminum, alkali, and alkali-earth bases as a result of their absorption by plants, and also by leaching. The high silica content is due to a certain degree to biological accumulation; it is inherent to sheep's fescue to hold it. As a result of the foregoing, the molecular ratio of $SiO_2:AL_2O_3$ and $SiO_2:Fe_2O_3$ widens in the fine earth as compared to the rock.

Phosphorus and sulfur accumulate in this fine earth, but in much lesser amounts than in the fine earth under lithophyllic vegetation.

A comparison of the total composition of sandstone and fine earth under moss and sheep's fescue (Table 2) shows more clearly than in the case of granite the characteristics of the process of soil formation. As in the case of the fine earth under moss there is a clear removal of SiO_2 from the fine earth under sheep's fescue which, as mentioned earlier, is inherent for the primary stages of soil formation. The aluminum and iron contents on the other hand, are considerably higher in the fine earths than in the rock, apparently as a result of their residual accumulation; this is more clearly shown by the molecular ratios of $SiO_2:Al_2O_3$ and $SiO_2:Fe_2O_3$. Calcium, magnesium, phosphorus, and sulfur concentrate in the fine earth as a result of their intense biological accumulation, whereby P_2O_5 and SO_3 accumulate to a lesser degree than in the fine earth over granite. Finally, in the case of the potassium content we must repeat the same as we said about granite and the three types of fine earths on it, with the only distinction being that the molecular ratio of $SiO_2:K_2O$ is much narrower here.

The foregoing data on the comparative study of the chemical composition of rock and fine earth agree with the results of investigations published earlier (15, 4, 7); but certain data (18, 17, 12, 11) differ considerably from those obtained by us. This is attributable to different bioclimatic conditions than to those which are characteristic of Northern Kazakhstan. The primary stages of soil formation under the bioclimatic conditions of Northern Kazakhstan and areas similar to it are characterized, as was shown earlier, by a decrease of silica in the fine earth, and an increase of the amount of calcium, magnesium, phosphorus, and sulfur as a result of biological accumulation. The potassium content in the fine earth, on the other hand, decreases as compared to the rock, in spite of its intense absorption by plants. The amount of sesquioxides increases at the expense of the loss of silica and as a result the molecular ratio of $SiO_2:R_2O_3$ narrows. According to investigations of Targul'yan, under conditions of the arctic and moss-lichen tundras, as well as the mountain forest tundra of Eastern Sayan (characterized by drizzle), the formation of primary soils is accompanied by the insignificant removal of silica, alkali, and sometimes calcium and magnesium; the content of sesquioxides increases, on the other hand. In the northeast of the Chinese People's Republic the process of formation of primary soils proceeds differently, according to Gorbunov and Sun Da-chen. These authors showed that in the course of 300 years a considerable amount of silica, sodium, calcium, and somewhat less potassium and magnesium, were removed from the initial rock (lava). The latter elements, as the authors report, become part of clay minerals and therefore become less mobile. As can be seen from the work of Troitskiy (18), even more silica, alkali, alkali earths and sulfur are removed from the

Table 2

Total chemical analysis of quartz sandstone and fine earth

Sample No.	Sample investigated	Ignition loss	In % of ignited sample										
			SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	SO_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{K_2O}$
	Sandstone	0,59	84,12	6,83	0,65	0,56	0,35	3,77	0,45	0,26	20,9	341,4	34,8
4	Fine earth under sheep's fescue	41,81	73,31	12,29	1,33	1,37	0,82	2,02	1,31	1,22	11,0	146,9	57,0
5	Same under moss Polytrichum p.	17,68	77,38	13,63	1,82	1,32	0,87	1,43	0,87	0,80	9,4	112,9	84,7

Note: Comma represents decimal point.

fine earth formed on the initial rock under conditions of a subtropical climate; the content of sesquioxides, on the other hand, increases greatly. Finally, in a tropical climate the first stages of soil formation are accompanied by an even deeper change of the initial rock (12). The forming product is not saturated with cations. The molecular ratio of $SiO_2:R_2O_3$ in its clay fraction ($< 2\,\mu$ in diameter) somewhat exceeds 2 or is close to 2. Consequently, in a tropical climate the product of the first stages of soil formation rapidly acquires an allite nature.

As we can see from the brief description of the results of the study of the first stages of soil formation, the direction and intensity of their development are governed by bioclimatic conditions. However, the first stages of soil formation in all cases are accompanied by a greater or lesser removal of SiO_2 and a corresponding increase of R_2O_3 in the fine earth, independent of bioclimatic conditions. The fact (which was established by Polynov a long time ago) of the removal of SiO_2 from the rock during the first stages of soil formation under eluvial conditions is apparently true even for Antarctica, judging from the investigations made by Glazovskaya (10).

Let us examine the results of determinations of the ash composition of plants (Table 3).

From the data in Table 3 one can see that the ash content in lichen on granite is 5%; that of moss on granite is even higher; and sheep's fescue on granite has the lowest ash content. Further, there is a great difference in the ash composition of plants and that of granite and sandstone. In spite of the insignificant content of calcium, magnesium, and potassium in these rocks, their accumulation in the ash of plants is several times higher. In particular, if the molecular ratios of $SiO_2:K_2O$ in granite and sandstone are 43.2 and 34.8, respectively, in the ash of lichen, moss, and sheep's fescue on granite, as well as in the ash of moss and sheep's fescue on sandstone, they are considerably lower. This is especially pronounced in the ash of lichen. The ash of plants is characterized by a narrower molecular ratio of $SiO_2:Fe_2O_3$ than the rock, which is an evidence of the removal of the former and comparative accumulation of the latter. It must be noted that because of the more intense uptake of silica by sheep's fescue, the $SiO_2:Fe_2O_3$ ratio in its ash is much wider. The increased amount of bases, phosphorus, and sulfur in the ash of plants as compared to the rock is attributable to the selective absorption of these elements. Thus, for instance, according to the intensity of absorption by lichen, expressed in absolute percentages, the elements are distributed in the following decreasing order: Ca–SiO_2–K–Mg–S–P–Fe. The ash of the Ceredoton purpurus moss is distinguished from that of lichen by a higher silica and iron content and a considerably lower content of the other elements, except sulfur. The order in which the elements are absorbed is the following: SiO_2–Ca–K–S–Fe–P–Mg.

The foregoing data show that Mg occupies the last place according to absolute content in the ash of moss, while this place is occupied by Fe in the ash of lichen; as far as the content of the other elements is concerned there is no substantial difference between the lichen Parmelia Sp. and the moss Ceredoton purpurus.

The sheep's fescue from the granite differs from lithophyllic vegetation not only by its lower ash content, but also by a different quantitative composition of the ash, which is characterized by a considerably higher SiO_2 content and a low amount of Ca, as compared with the ash of lichen and moss; as far as the other elements are concerned the ash of sheep's fescu is closer to that of lichen.

The order in which the elements are absorbe by sheep's fescue on granite is the following: SiO_2–K–Ca–P–Mg–S–Fe. The moss Polytrichum piliferum differs little in its ash content from Ceredoton purpurus, while the ash content of sheep's fescue on sandstone is considerably lower than that of sheep's fescue on granite. The ash of Polytrichum piliferum is characterized by a high content of magnesium, reaching 6% in it as compared to 2% in the ash of the foregoing moss. There is no difference between them as far as the SiO_2 content is concern

Table 3

Chemical analysis of plant ash, % of pure ash

Sample No.	Sample investigated	Pure ash, %	SiO_2	Fe_2O_3	CaO	MgO	K_2O	P_2O_5	SO_3	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{K_2O}$
	Granite	—	70,51	1,55	1,78	0,83	2,55	0,25	0,28	120,9	43,2
1	Parmelia lichen	5,00	23,31	1,53	26,29	5,05	20,04	4,31	5,01	40,4	1,8
2	Ceredoton purpurus moss	6,37	37,89	4,41	21,61	2,32	16,06	3,37	5,26	29,0	3,6
3	Sheep's fescue, Festuca ovina	3,86	51,38	1,66	8,10	5,60	20,29	5,81	4,54	82,2	4,0
4	Quartz sandstone	—	84,12	0,65	0,56	0,35	3,77	0,45	0,26	341,4	34,8
5	Polytrichum pilifer moss	5,89	39,16	3,39	13,13	6,19	12,89	4,45	4,59	30,8	5,0
6	Sheep's fescue, Festuca ovina	6,40	56,67	0,66	9,22	3,54	19,34	3,62	2,73	230,1	4,6

Note: Comma represents decimal point.

the content of the other elements, however, is lower in the ash of moss on sandstone than in that of moss from granite. The order in which the elements are absorbed, with the exception of Mg and Fe, is in many ways the same as for Ceredoton purpurus: SiO_2—Ca—K—Mg—S—P—Fe. The ash of sheep's fescue on sandstone is considerably richer in SiO_2 (which explains its higher ash content) and has a little more calcium; the other elements in the ash of sheep's fescue from sandstone, as in the ash of moss from it, are contained in lesser amounts than in the ash of sheep's fescue from granite, which is attributable to the low content of these elements in the sandstone. In spite of this, the order in which the elements are absorbed by sheep's fescue on sandstone is the same as for sheep's fescue on granite: SiO_2—K—Ca—P—Mg—S—Fe. Consequently, the selective absorption capacity of plants, as expressed in absolute values, remains the same, independent of rock composition.

The examination of data in Table 3 leads to the following conclusion: the number of elements absorbed by plants under given bioclimatic conditions depends both on the type of plant and their content in the rock.

Below we give the biological series according to Polynov.

Lichen Parmelia Sp. from granite

$$\frac{S}{17{,}9} - \frac{P}{17{,}2} - \frac{Ca}{14{,}9} \mid \frac{K}{7{,}84} - \frac{Mg}{6{,}13} \parallel \frac{Fe}{1{,}11} - \frac{SiO_2}{0{,}33}$$

Ceredoton purpurus from granite

$$\frac{S}{18{,}8} - \frac{P}{13{,}5} - \frac{Ca}{12{,}1} \mid \frac{K}{6{,}29} \parallel \frac{Fe}{2{,}8} - \frac{Mg}{2{,}2} - \frac{SiO_2}{0{,}53}$$

Polytrichum piliferum from sandstone

$$\frac{Ca}{23{,}4} - \frac{S}{17{,}6} - \frac{Mg}{17{,}6} \mid \frac{P}{9{,}1} \mid \frac{Fe}{5{,}2} - \frac{K}{3{,}4} \parallel \frac{SiO_2}{0{,}46}$$

Festuca ovina, sheep's fescue, from fine earth on granite

$$\frac{K}{25{,}7} - \frac{Mg}{18{,}1} - \mid \frac{Ca}{7{,}5} - \frac{P}{6{,}3} - \frac{S}{5{,}2} \parallel \frac{Fe}{1{,}08} - \frac{SiO_2}{0{,}53}$$

Festuca ovina, sheep's fescue, from fine earth on sandstone

$$\frac{K}{9{,}57} - \frac{Ca}{6{,}73} - \frac{Mg}{4{,}32} \mid \frac{P}{2{,}7} - \frac{S}{2{,}2} \parallel \frac{SiO_2}{0{,}77} - \frac{Fe}{0{,}5}$$

The biological series of lichen shows that it absorbs with greatest intensity S—P—Ca, a slightly lesser intensity K and Mg and very little Fe and SiO_2. The biological series of Ceredoton purpurus is very close to the biological series of the lichen Parmelia; the only difference lies in that Mg and Fe have changed position with them. In spite of the large amount of SiO_2 in the ash of lichen and moss as a result of its high content in the rock, it occupies the last place in the biological series. The biological series of Politrichum piliferum differs slightly from the preceding series, however, among the number of most intensely absorbed elements are also Ca—S—Mg—P; K and Fe are intensely absorbed by this moss, and SiO_2 is especially weakly absorbed because of the foregoing reasons.

In spite of the considerable difference in the SiO_2, Mg, P, and S content in the ash of sheep's fescue on fine earth over granite and that on fine earth over sandstone, there is no great difference in the order of distribution of elements in the biological series. In both cases K, Mg, Ca, P, and S are among the number of intensely absorbed elements, but the absolute organogens P and S, in contrast to lithophyllic vegetation, are not located in the first place in the series. Moreover, in comparing the series one can see that sheep's fescue on sandstone absorbs all elements with a lesser intensity than sheep's fescue on granite. The biological series obtained by us are very close to the published series (4, 6, 13, 15). Thus, the series for lichen show that the number of most intensely absorbed elements includes S, P, Ca, K, and sometimes Mg; the least intensely absorbed elements are Al, Fe, and SiO_2.

According to the data of all authors, mosses absorb P, S, Ca, and Mg with the greatest intensity. Potassium is absorbed by them to a lesser degree than by lichens, whereas iron is absorbed more strongly. Thus, it can be seen from the ash composition of lichens and mosses and their biological series that the primary lithophyllic vegetation, by concentrating P, Ca, S, and K and absorbing other mineral elements necessary to them, creates a substrate which is suitable for the colonization by higher plants. The same analogy is found between the biological series of sheep's fescue in the Caucasus (13) and our series; the only differences are that according to our data Mg belongs to the more strongly and S to the more weakly absorbed elements. The group composition of humus of primitive soils has been studied very little. Aydinyan (1), Assing (5), and Aleksandrova (3) found certain peculiarities in the composition of humus of these soils. The results of their investigations allow the following conclusions to be made:

1) the content of bitumen in the composition of humus varies within wide limits, namely from 5% to 21% of the C in the initial sample; 2) the composition of humus is characterized by a high content of a non-hydrolyzable residue — 28% to 50% of the C in the initial sample; 3) in the composition of humus of the majority of primitive soils studied the content of fulvic acids exceeds that of humic acids, as a result the ratio between the C of humic acids and the C of fulvic acids in them is <1; 4) most of the humic acids are represented by mobile forms, the carbon of which is 70%-100% of the carbon content in humic acids.

The data in Table 4 gives an idea of the amount of main groups of humic substances

Table 4

Carbon and its content of humic acids, fulvic acids, and nonhydrolyzable residue

Sample No. and place taken	Sample investigated	Rock	Depth, cm	Organic C, %	C, % of total content in initial sample					
					Humic acids	Mobile humic acids	Mobile humus acids in % of C_h	Fulvic acids	C_h:C_f[a]	Nonhydrolyzable residue
Dzhalandin hill 2	Fine earth under Ceredoton purpurus	Granite	0—3	18,51	23,22	17,08	73,5	29,52	0,78	33,5
6	Primitive soil under sheep's fescue and moss	"	0—3	5,07	20,84	11,04	60,0	28,76	0,72	28,5
			3—9	3,32	22,12	12,60	57,0	32,88	0,67	31,1
7	Same under Sedum	"	0—9	12,03	22,43	16,80	74,9	25,27	0,88	31,4
			9—20	7,76	21,55	16,50	76,5	20,06	1,07	41,5
Kiselev hill, 4	Fine earth under Sheep's fescue	Sandstone	0—10	6,11	18,61	12,7	68,2	28,00	0,66	32,1
5	Same under Polytrichum piliferum	"	0—5	10,76	24,69	20,5	83,0	32,00	0,77	30,8

[a] C of humic acids: C of fulvic acids

Note: Comma represents decimal point.

in the primitive soils of Northern Kazakhstan.[1]

They point to great variations in the content of organic carbon. It is especially high in fine earth under moss and Sedum; primitive soil under sheep's fescue has much less carbon. The carbon of primitive soils is mainly represented by humic acids, fulvic acids, and nonhydrolyzable residue, which altogether amount to 78%-87% of its total content in the initial sample. In this respect the results of our investigations agree with the data of the foregoing authors.

Further, one can see from Table 4 that mobile forms predominate in the composition of humic acids, the content of which varies from 60% to 80% of the total carbon of humic acids.

The amount of humic acids bound by calcium and stable R_2O_3 varies from 17% to 40%. The content of fulvic acids exceeds that of humic acids in all samples, except for one, and thus the ratio between the C of humic acids and the C of fulvic acids is <1; only in one case was the ratio between them 1. The predominance of fulvic acids over humic acids was also found by Aydinyan (1), Aleksandrova (3), and Glazovskaya (9). Assing, however, found that humic acids predominated considerably over fulvic acids in fine earth under moss (5). The predominance of humic acids over fulvic acids in fine earth on diorites under grass vegetation is pointed out by Aleksandrova. However, in the majority of cases the primary stages of soil formation were accompanied by the formation primarily of mobile humic and fulvic acids; the formation of humic acids bound by calcium and stable R_2O_3 is insignificant, which apparently is attributable to the nonsaturation of humus with bases.

As can be seen from Table 4, the content of the nonhydrolyzable residue is high and varies within wide limits; however, in the majority of cases its amount varies from 31%-33% of the carbon in the initial sample. Consequently, according to this index also the results of our investigations agree with the data published by other authors. As far as the composition of the nonhydrolyzable residue is concerned it is apparently represented to a great extent by not easily decomposed plant residues, as rightly assumed by Aleksandrova, and not by humic substances which are strongly bound with the mineral part of the soil. Could not the low content of humic acids, bound with calcium and stable R_2O_3, and the foregoing supposition be explained by the difficulty of the decomposition of plant residues? This should be verified by special investigations.

---

[1] The data were taken by us from the dissertation of L.I. Alekseyeva, written under the supervision of M.A. Vinokurov.

Conclusions

1. The primary stages of soil formation begin with the colonization of microorganisms and lichens on rock, which intensely decompose it mechanically and biochemically.

2. A comparison of the chemical composition of fine earth with that of rock shows that the removal of SiO_2 and the accumulation of Al_2O_3 and Fe_2O_3 are inherent of the first stages of soil formation under eluvial conditions. In addition Ca, Mg, P, and S accumulate intensely in the fine earth and potassium salts are removed from them.

3. Among the elements most intensely absorbed by lichen, moss, and sheep's fescue, are S, P, Ca, K, and Mg. Differences between the biological absorption series of the foregoing plants leads to the rearrangement of the elements within their given group.

4. As far as the content of mineral elements is concerned, fine earths occupy an intermediate place between rock and the ash of plants.

5. Primitive soils are distinguished by a high humus content, whereby soils under lithophyllic vegetation and Sedum are richer in it than the soil under sheep's fescue.

6. The humus of primitive soils consists primarily of three groups of substances: humic acids, fulvic acids, and non-hydrolyzable residue, together comprising 78%-87% of the carbon in the initial sample.

7. The humic acids of primitive soils are represented primarily by free forms and forms bound with mobile R_2O_3.

8. The ratio between the C of humic acids and the C of fulvic acids is less than 1.

9. The non-hydrolyzable residue in most of the primitive soils studied was 31%-33% of the total carbon content in the initial sample.

Received July 18, 1960

BIBLIOGRAPHY

1. AYDINYAN, R. KH. 1948. Comparative study of the composition of organic matter in the primary products of weathering, their colloidal fractions and soils. Soobshch. Labor. agrokhimii Akad. Nauk Armyanskoy SSSR. No. 1.
2. AYDINYAN, R. KH. 1949. Exchange of substances and the formation of mineral colloids in the primary stages of soil formation on massive-crystalline rocks. Dokl. Akad. Nauk SSSR. 67(4).
3. ALEKSANDROVA, I. V. 1953. Processes of humus formation in primitive soils. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 41.
4. ASSING, I. A. 1949. Initial stages of weathering and soil formation on massive-crystalline rocks. Probl. sov. pochvov. sb. 15.
5. ASSING, I. A. 1950. Organic matter in the matter in the primary stages of soil formation. Izv. Akad. Nauk KazSSR, Seriya pochv. No. 6.
6. BOBRITSKAYA, M. A. 1950. Absorption of mineral elements by lithophyllic vegetation on massive-crystalline rocks. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 34.
7. GLAZOVSKAYA, M. A. 1950. Weathering of rocks in the nival zone of the Central Tyan'-Shan'. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 34.
8. GLAZOVSKAYA, M. A. 1950. Influence of microorganisms on the weathering of primary minerals. Izv. Akad. Nauk KazSSSR. No. 86.
9. GLAZOVSKAYA, M. A. 1952. Friable products of rock weathering and primary soils of the nival zone of Terskei Ala-Ten. Tr. In-ta geografii Akad. Nauk SSSR. Vol. 49.
10. GLAZOVSKAYA, M. A. 1958. Weathering and primary soil formation in Antarctica. NDVSH, geologo-geografich. nauki. No. 1.
11. GORBUNOV, N. I., SU TA-CHEN. 1960. Formation of secondary minerals during the first stage of soil formation. Dokl. sov. pochv. k VII Mezhd. kongr. v SSHA.
12. LENEUF, N. 1960. Weathering of carbonate-alkali granites and granitoids and soils in the forest zone of the Ivory Coast. Review by Ye. V. Lobova. Pochvovedeniye, No. 11.
13. PARFENOVA, YE. I. 1950. Investigation of primitive mountain-meadow soils on the diorites of the Magisho Range (Northern Caucasus). Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 34.
14. POLYNOV, B. B. 1934. Weathering crust. Moscow-Leningrad.
15. POLYNOV, B. B. 1945. First stages of soil formation of massive-crystalline rocks. Pochvovedeniye, No. 7.
16. POLYNOV, B. B. 1956. Geological role of organisms. Selected works of B. B. Polynov. Akad. Nauk SSSR.
17. TARGUL'YAN, V. O. 1959. First stages of weathering and soil formation on igneous rocks in the tundra and taiga zones. Pochvovedeniye, No. 11.
18. TROITSKIY, A. I. 1949. Exchange of mineral elements between the soil and vegetation. Probl. sov. pochvov. Akad. Nauk SSSR. Sb. 15.
19. YARILOVA, YE. A. 1947. Role of lithophyllic lichens in the weathering of massive-crystalline rocks. Pochvovedeniye, No. 9.

DUST STORMS IN SOUTHERN UKRAINE IN THE SPRING OF 1960

V. A. KULIKOV, Administration of Hydrometeorological Service, Ukrainian SSR, Kiev

Dust storms are harmful to agriculture. They cause the deflation of plantings, mechanical damage to plants, severe drying of soil, and the removal of the upper, fertile layers — thus creating severe losses in agricultural production. Dust storms also cause damage to other branches of the national economy: transportation, communication, aviation, etc. Suspended dust particles, which are lifted by air currents, cause atmospheric turbidity and reduce both horizontal and vertical visibility, which greatly interferes with the air transport. During severe storms drifts form in individual sections of roads, plantings near roads, and various protective installations. Sometimes when winds are strong during dust storms they damage telephone and telegraph lines.

Dust storms are rather frequent in the steppe regions of the southern Ukraine. They occur almost every year, most frequently in spring when large plowed areas are not yet covered with vegetation. The traces of former dust storms are still to be found in forest shelterbelts in the form of soil drifts, which have become covered by vegetation and sod with the years. Usually they do not exceed 0.3-0.4 m in height. To a certain extent we can judge the intensity of former dust storms by the size and height of these drifts.

According to their intensity, duration, and extent, the dust storms of 1960 were the severest storms in the last 2-3 decades in the Ukraine. They occurred several times in March and April of 1960 and extended over large territories in the southern and certain central regions of the Ukraine. There were three storm periods during this time: from March 18 to 23-24, from April 3 to 9-10, and from April 11-12 to 18. Thus, during the period from March 18 to April 18, 1960, the dust storms lasted 20-21 days.

The occurrence of strong winds, causing dust storms in March, may be explained by the following synoptic situation.

On March 17 a large high cyclone moved over the Balkans and the Apennines, which caused a drop in atmospheric pressure in the Black Sea area. At the same time a high-pressure anticyclone was moving from the Barents Sea toward the central regions of the European USSR. The drop in pressure in the Black Sea area on the one hand and the movement of the anticyclone toward the south of the European USSR, on the other hand, caused an increase in pressure gradients over the southern regions of the Ukraine. During the next 5-6 days the magnitude of the pressure gradients over these regions remained the same. The increase in pressure gradients caused an increase in easterly winds up to 18-20 m/sec in the Crimea, and the Kherzon and Zaporozh'ye Oblasts'.

The synoptic conditions which caused an increase in wind in April were similar to the foregoing.

The dust storm which began on March 18, 1960, (Table 1) embraced the steppe regions of the Crimea, the entire Zaparozh'ye and Kherson Oblasts', and partially extended over certain regions of the Stalin and Nikolayev Oblasts'. In the Stalin and Nikolayev Oblasts', in the north of the Saparezh'ye Oblast', and in the south of the Kherson Oblast', it lasted 1-2 days, while in the remaining part of the territory it persisted to March 23-24, with a short letdown or abatement on March 20. The dust storm reached its maximum intensity on March 22. It was most pronounced in the steppe regions of the Crimea (Krasnogvardeysk, Dzhankoy, Chernomorsk rayons, etc.) and in the extreme south of the Zaporozh'ye and Kherson Oblasts'.

According to the data of the Klepinino agricultural meteorological station (Krasnogvardeysk rayon, Krym Oblast') the wind velocity reached 24 m/sec on the day when the dust storm was most intense; visibility was reduced to 300-500 m; automobile traffic moved very slowly during the daytime with lights on; and there was some damage to telephone and telegraph lines.

At the beginning of the dust storm, soil moisture conditions were good over the entire territory, while in the Nikolayev Oblast', the Stalin Oblast', the northern regions of the Kherson Oblast', and in the Zaporozh'ye Oblast' the soil was even frozen, which considerably reduced the deflation of plantings and the removal of the upper soil layers. Therefore this dust storm did not inflict much damage to agricultural crops, except for certain regions of the Krym, Kherson, and Zaporozh'ye Oblasts', where in certain cases winter crops were deflated and covered with drifts of soil dust.

Those winter crops were primarily subject to deflation which were late and poorly developed, especially winter barley. This crop was considerably damaged in the Dzhankoy, Primorskiy, Lenin, Chernomorsk, and other rayons of the Krym Oblast'.

In the steppe regions of the Crimea, in the south of the Kherson Oblast', and in the Zaporozh'ye Oblast', there were cases where the upper, pulverized soil layers were removed in plowed fields having undergone presowing cultivation or already seeded with early spring grain crops. Well-tillered winter plantings, bordering on bare fields were subject to drifts. Here sand and fine soil particles, torn off and carried by the wind, were deposited on the winter plantings in a narrow strip 30-50 m wide and 2-4 cm thick. Since the thickness of these drifts was insignificant, there was no serious damage to the plants. The main stems of the plants were fully preserved and, after the storm stopped, grew rapidly, reaching the height of those plants which were not affected by the drift. However, even these small drifts caused the thinning of plantings as a result of the dying off of side shoots and weakly developed plants.

According to investigations and reports from the station, damage was caused during the March dust storm to agricultural crops in the Primorskiy, Lenin, Krasnogvardeysk, Sakskom, Chernomorsk and other rayons of the Krym Oblast'. Damage was sustained also by plantings in a number of areas in the Kherson and Zaporozh'ye Oblasts'.

According to the report of the "Zernosovkhoz Kirovskiy" meteorological station in the Kiev sovkhoz, Chernomorsk rayon, Krym Oblast', agricultural crops in certain crop rotation fields sustained damage by deflation and drifts, whereby the damage to winter barley amounted to as much as 50% in individual cases. On individual farms weak plantings of winter barley perished entirely. Gardens and vinyards were not damaged. Drifts were small in forest shelterbelts. Even in forest belts bordering on bare, plowed areas, the drifts did not exceed 20-30 cm.

The dust storm resumed in the Krym Oblast' on April 3, 1960 (Table 1) and began to move gradually toward the north, reaching the Kherson, Zaporozh'ye, Nikolayov, Odessa, Stalin, Lugan', Dnepropertrovsk, as well as the south in the Khar'kov, Poltava, and Korovograd Oblasts' by April 6-7. It lasted in the Krym, Kherson, and Zaporozh'ye Oblasts' until April 8-9 and until April 9-10 in the rest of the territory. This time it reached its greatest intensity in the Krym, Kherson, and Zaporozh'ye Oblasts'. The maximum wind velocity here was up to 20-25 m/sec, with gusts reaching 34 m/sec and more. Atmospheric turbidity increased to such an extent that in the absence of clouds during the daytime the sun appeared as a pale disc and sometimes disappeared completely. In certain areas visibility dropped to 50-100 cm. Relative humidity during the noon hours dropped to 15%-30% over most of the territory. Field work was discontinued almost everywhere.

This dust storm was preceded by a long rainless period. The upper soil layer dried out and was in a dry or slightly moist condition. The increase in wind and the drying of the upper soil layer promoted the more severe deflation of agricultural plantings and the removal of soil from bare areas, as well as the transport and deposition of soil particles in protected areas.

As during the March dust storm, deflation and soil removal occurred primarily in tilled fields, free of vegetation, large areas of which were now sown with early spring crops. The removal of the upper soil layers reached such a degree that in certain parts of fields the wind carried away not only dust and fine earth, but also large granular aggregates. Deflation and soil removal frequently reached the depth of spring crop seeds, i. e., 5-6 cm. In these cases seeds and weakly-rooted young shoots were carried away with the soil, leaving only large soil clods behind. Deflation and the removal of the upper soil layers were most intense in open fields, located on elevated relief and in unprotected windward slopes. Here almost the entire friable upper soil layers were removed from bare areas (Fig. 1).

Deflation and the removal of soil also reached a considerable degree in coarse-textured sands, sandy loam, and structureless pulverized soils which were not covered by plants. Such type of soil erosion was very pronounced in the Tsyurupin and Golopristan' rayons of Kherson Oblast', located in the zone of the Aleshkov deserts, and also in the Krasno-Perekop, Dzhankoy, and other rayons of the Krym Oblast' on structureless solonetzic and chestnut soils.

Soil erosion by deflation and removal of the upper layers during the April dust storm reached tremendous proportions in the foregoing areas. For instance, on those fields where deflation reached 5-6 cm, up to 500-600 m³/ha of the most fertile soil, rich in humus, disappeared without a trace. Even with an insignificant soil removal of 1-2 cm, which took place over wide areas, the losses of humus per hectare were at least 5-10 metric tons for soils in the southern Ukraine.

If during the March dust storm only very weak plantings of winter crops were damaged over small areas, during the April storm extensive damage was sustained in many regions of the Krym, Kherson, Zaporozh'ye, and other Oblasts' of the extreme south of the Ukraine.

At this time weakly developed and thin plantings of winter crops suffered most from deflation and mechanical damage. Winter crops perished completely on individual farms of the Kerch' Peninsula. This occurred in such places where, as a result of insufficient soil moisture in autumn, winter crops stopped to grow primarily during the stage of the third leaf or germination. Frequent warm spells and sharp temperature fluctuations in the winter of 1959-1960 made them even weaker. In spring, after the resumption of growth,

Table 1

Intensity and duration of dust storms in the spring of 1960 according to Oblasts'

Station	Period	Duration, hr	Prevailing wind direction and maximum velocity, m/sec	Relative humidity, at 1 p. m., %	Soil
Crimea					
Chistopol'ye	March 18-23	68	E.—20	35	Moist
	April 3-7	73	N. E.—18	29	Dry
Klepinino	March 18-24	78	E.— N. E.—18	25	Moist
	April 3-7	67	E.—N. E.—18	36	Dry
Zernosovkhoz	March 18-23	69	E.—N. E.—16	42	Moist
Kirovskiy	April 3-8	82	E —18	28	Dry
Dzhankoy	March 18-24	61	E.—N. E.—16	65	Moist
	April 4-8	85	E.—16	38	Dry
Zaporozh'ye					
Bot'yevo	March 18-23	63	N. E.—20	20	Slightly moist
	April 4-9	98	N. E.—18	19	Dry
	April 12-18	121	E.—12	15	"
Prishib	March 18-19	11	E.—12	48	Moist
	April 7-8	14	E.—16	18	Dry
	April 13-15	20	E.—16	15	"
Kherson					
Ashaniya Nova	March 18-23	40	E.—20	25	Moist
	April 6-8	56	E.—24	21	Dry
	April 12-13	10	E.—14	16	"
Nizhniye Serogozy	March 18-23	58	E.—18	27	Moist
	April 4-8	61	E.—16	22	Dry
	April 12-18	52	E.—12	16	"
Nikolayev					
Bashtanka	March 18-19	8	E.—16	52	Moist
	April 7-9	34	E.—N. E.—20	14	Dry
	April 13, 15	6	E.—N. E.—14	8	"
Odessa					
Serbka	March 18	4	E.—14	66	Moist
	April 6-8	28	E.—14	24	Dry
	April 18	2	E.—N.E.—14	16	"
Stalin					
Zhdanov	March 18-20	34	E.—16	39	Moist
	April 7-8	35	E.—20	38	Dry
	April 12, 15-18	50	E.—20	18	"
Udachnoye	April 8-10	31	E.—20	15	"
	April 16	6	E. —S. E. —16	16	"
Lugan'					
Starobel'sk	April 9-10	7	E. —S. E. —16	20	Dry
Dnepropetrovsk					
Gubinikha	April 8-9	9	E.—16	30	Dry
	April 16-17	37	E.—16	17	"
Nikopol'	April 7-8	14	E.—20	25	"
	April 17-18	6	E.—12	17	"

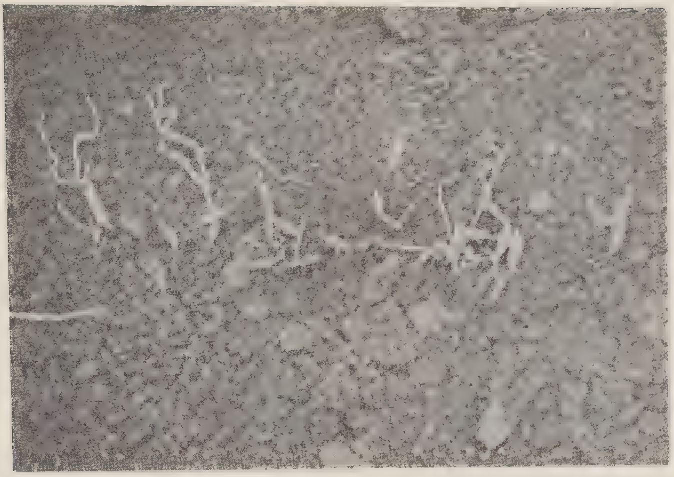

Fig. 1. - Deflation of spring barley in the kolkhoz "Rossiya," Krasnogvardeysk rayon, Krym Oblast'

these plantings proved to be very thin, and the foliage of many plants had died. It is only natural that these plantings could not withstand the dust storm and perished.

The April dust storm inflicted especially great damage to winter barley, since a large part of it resumed spring growth in a weakened condition. The first plantings to be subjected to deflation were those on unprotected, elevated areas. However, well-developed plantings of barley which stood wintering well were almost not damaged at all.

Winter wheat and rye suffered less from the dust storm. They were subject to deflection to a considerably lesser degree than winter barley; this is attributable to the fact that winter wheat and rye in the area of the dust storm wintered well and were in better shape during the growing period in spring.

In a number of cases plantings of winter wheat and rye were covered with soil dust. This type of damage was primarily sustained by well-developed plantings bordering on the windward side of bare fields. The dust and fine earth transported by the wind was deposited in winter crop plantings in the form of strips 60-100 m wide. The thickness of the drifts averaged 5-6 cm, and often reached 10-12 cm and more. In a number of cases soil drifts occurred during the storm at the same place twice, and their thickness here was especially great. But, as a rule, well-developed winter crops did not perish completely. The plantings just became thinner because of the dying of side shoots, but not to such a degree that resowing was required. The undamaged main stems grew rapidly.

The thinning of planting as a result of the drifts may be shown by the following example. One of the fields of winter wheat at the Crimean State Agricultural Experiment Station borders on the northeast on a field plowed in the fall. During investigations made before the dust storms this winter wheat was in good condition, the density of the stand was 200 stems per linear meter, and their height was 10 cm. After the March dust storm drifts 40-50 m wide and 2-4 thick formed in the winter wheat field on the side of the plowed field. The April storm increased the drift, which became 100-120 m wide and 10-12 cm thick in the area of the earlier drift and 4-5 cm in the remaining part. In spite of such a heavy drift, the plants did not die altogether but only thinned out. Where the drift was heavy the density of the stand decreased to 105 stems per linear meter because of the dying out of the side shoots. The stems of the plants became slightly thinner. In those areas where the soil drift was 4-5 cm the density of the stand was 155 plants. In both cases the damage was not such that it required sowing winter wheat anew or undersowing.

The degree of damage to winter plantings depended to a great extent on the form of relief. In depressed areas and on leeward slopes it was more severe than in level areas. In addition to deflation and drifts, the dust storm caused mechanical damage to the plants. The small soil and sand particles driven with a great force by the wind damaged the shoot of plants, covering, shredding, and breaking it. Mostly weak plants and plants at the edges of fields were subject to such a damage. Well-developed winter crop plantings located in level areas and at a distance from bare areas remain uninjured. This indicates that they are more resistant to the damaging effect of dust storms.

Gardens and vinyards also remained untouched by the April dust storm, even though drifts formed in individual vineyards in certain areas of the Krym Oblast' (Sask, Yevpatoriya, and other rayons). Here drifts occurred primarily in vineyards located on leeward slopes. The area of such vineyards is small and the drifts were small, about 10-20 cm.

In concluding our description of the April dust storm we must discuss the protective effect of forest belts.

The results of inspection proved that forest belts are a reliable means of protecting agricultural crops from the damaging effect of dust storms. By reducing wind velocity and arresting the fine earth and soil dust carried by the wind, forest belts protect plantings from deflation, drifts, and mechanical damage. However, individual forest belts, located along roads or at the edges of farms, do not afford full protection to fields against dust storms. Such forest belts only arrest and collect a large amount of soil dust, often burying themselves in these dust "banks." During the April dust storms dust "banks" up to 2 m high and 15-20 m wide formed in certain forest belts (10 m wide) oriented from north to south and bordering on the leeward side by bare fields, and individual "tongues" extended 30-35 m on the leeward side (Fig. 2). The crest of these drifts was 12-15 m wide.

Proceeding from the foregoing values we can calculate that 30,000-40,000 m³ of soil accumulated over 1 km along such forest belts.

The largest drifts in forest belts occurred in the central and western regions of Crimean, in the south of the Kherson and Zaporozh'ye Oblasts', and in certain areas of the Stalin Oblast'.

Reliable protection against dust storms is afforded by forest belts edging each crop rotation field. This is confirmed by the so-called Molochan crop rotation of the Ukrainian Scientific-Research Institute of Animal Husbandry in the Steppe Regions of the Ukraine im. M. F. Ivanov (Askaniya Nova), where all fields are bordered by forest belts. The size of these fields is 400-500 x 800-1000 m. The long sides of the fields run from north to south. The width of the forest belts is 10-12 m, the height of the stands is 3-5 m, and they are kept in good condition. Because of the presence of forest belts neither deflation nor soil drifts occurred behind the second row of plantings, whereas crops were damaged in unprotected fields on the same farm.

In addition to agriculture, the dust storm caused great damage to roads. In many areas of the southern Ukraine drifts covered road shoulders, drainage ditches, snow fences, and in certain areas even roads. Many natural tree stands were buried under soil dust "banks." Individual buildings in the open steppe and at the edges of settlements were buried under the drifts.

After subsiding for a short period in the southeastern and southern parts of the Ukraine (except for the Crimea), the dust storm resumed for a third time on April 11-12, 1960. This time its center of activity was the southern regions of the Zaporozh'ye Oblast' (Priazov, Melitopol', Novo-Vasil'kov, etc.) and the adjoining areas of the Stalin and Kherson Oblasts'. It lasted, with interruptions of 1-2 days, until April 18, 1960.

The meteorological conditions during the foregoing dust storm were similar to those of the first storm, but the wind velocity was lower. This time winter crop plantings were strong enough and the dust storms did not cause much damage. However, the young shoots of early spring grain crops were partly damaged in a number of southeastern rayons of the Ukraine.

The duration of the rainless period, low relative humidity, which in the noon hours dropped to 15%-25%, and the strong, dry easterly winds promoted intense evaporation from the soil, especially in fields where deflation took place. The loss of moisture by the soil during the dust storms amounted to about 3-5 mm/24 hr, or 30-50 metric tons/ha. Such an ineffective loss of water caused a severe drying of the soil.

Even this brief and incomplete description of dust storms in the spring of 1960 gives us an idea of the damage they caused to agriculture.

Under conditions of the socialist system of agriculture, having the most advanced agronomy in the world and equipped with a high machine technology, the harmful effect of dust storms can be reduced considerably and the damage to

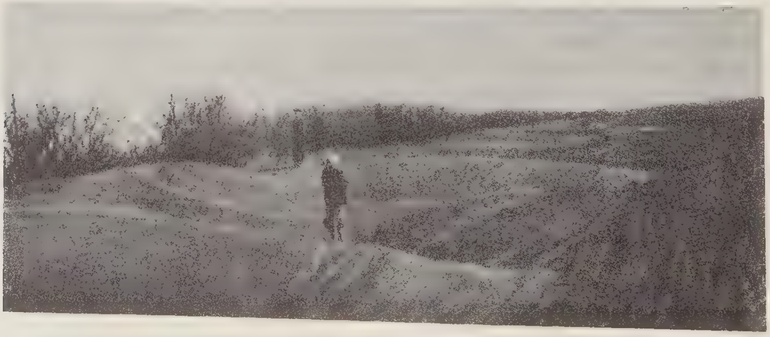

Fig. 2. - Drift in a forest belt bordering on a plowed field (Chernomorsk rayon, Krym Oblast') caused by a dust storm.

agricultural crops brought to the minimum.

The experience of many kolkhozes and sovkhozes shows that the most effective means of controlling dust storms are: the creation of forest shelterbelts at the edges of crop rotation fields; the retention and reforestation of sands; utilization of proper crop rotation; the improvement of the soil structure and the increase of its fertility; the use of scientifically-substantiated agricultural methods of raising crops in conformity with soil and climatic conditions; and the accumulation and retention of moisture in the soil, etc.

Received May 26, 1960

CHARACTERISTICS OF THE VERTICAL ZONALITY OF SOILS IN CENTRAL AFRICA

I. A. DENISOV, Tambov Regional Agricultural Experiment Station

The problem of the vertical zonality of soils in Central Africa has not been discussed much in the literature. The author had the opportunity to study the high-mountain soils of the large plateaus and mountain ranges of Ruanda-Urundi, which gradually rise from an elevation of 700 m to 3000 m above sea level. Because of the more or less regular increase in elevation, the characteristics of the vertical zonality of soils do not undergo sharp changes during the gradual transition from one soil group to another. Sharp changes in elevation are accompanied by changes in local climatic conditions. Such difficulties are found when studying high-mountain soils of isolated mountains in Central Africa, such as Mounts Kilimanjaro, Kenya, and Ruwenzori.

At elevations from 800-1500 m in Ruanda-Urundi, under the tropical climate with an annual precipitation of 900-1200 mm and a well-defined dry season, red and yellow lateritic soils are widespread, and sometimes black margalitic soils of hydromorphous origin are encountered.

Black margalitic soils are characterized by: a black color, a comparatively low humus content, fine texture, clay minerals of the montmorillonitic type, a high degree of base saturation, etc. (3, 4, 10, 11, 13). These soils are often associated with a "gilgay" type of relief, and are frequently saline. Carbonate concretions are often found in the lower part of the profile.

Lateritic soils are brightly colored tropical zonal soils, which are characterized by the strong decomposition of the mineral mass, reaching the almost complete disappearance of primary minerals (except for quartz), and the concentration of iron and aluminum oxides. According to the most recent data, the criteria for the classification of lateritic soils are the degree of development and the degree of saturation of the humus horizon, as well as the weathering of the mineral part of the soil. As we will see later, the first criterion is the basic one for subdividing the high-mountain soils of Central Africa. The lateritic soils of plains are subdivided according to this criterion into soils with well- and poorly-defined humus horizons.

Basically the following lateritic soils are distinguished according to the degree of weathering of the mineral portion: the so-called latosols and ferrisols, and sometimes young tropical soils ("dark" or "brown").

Latosols are characterized by a high degree of weathering, which is expressed in the reduction of the content of fine silt particles (2-20 μ in diameter), and in the almost complete absence of primary minerals, except for weathering-resistant minerals, such as quartz. The clay is immobile, there are no clay coatings on the surface of structural aggregates. Latosols are generally distinguished by the pronounced predominance of some separates and the almost complete absence of others. According to mineralogical composition they differ sharply from ferrisols and dark young soils by the predominance of clay minerals of the type of kaolinite, often accompanied by gibbsite. Ferrisols are characterized by a lesser degree of weathering of the mineral portion of the soil. They are distinguished by a large amount of primary minerals or their hydrated forms, such as sericite, chlorite, etc., even though they are less rich in this respect than young tropical soils.

Clay coatings are often found on the surface of the structural aggregates of ferrisols, which is an indication of the mobility of clay. But clay does not accumulate by illuviation in these soils. They are comparatively rich in particles 2-20 μ in diameter. The ratio between these particles and clay particles ($< 2\ \mu$ in diameter) varies from 0.5-0.15. In latosols this ratio is always lower than 0.15, decreasing to 0.03-0.04, while in young soils it exceeds 0.5.

Ferrisols are not characterized by a clear differentiation between separates. They are distinguished by the presence of montmorillonite, illite, and other clay minerals in addition to kaolinite.

Young tropical soils develop on slightly weathered material and are therefore characterized by a relatively high amount of primary minerals, by an A-C type of profile, clay minerals of the type of illite and montmorillonite, a low content of kaolinite, the absence of gibbsite, and a weak differentiation between separate sizes.

The designations "ferri" and "latosols" are sometimes replaced by other names, but the essence of this subdivision, according to the degree of weathering of the mineral portions of soils, remains the same in the majority of recent classifications of tropical soils.

Lateritic soils of Central Africa, which are located in the zone of a moist dry season, are characterized by a gradual increase of clay particles with depth. This is due to the more favorable moisture conditions in the deep soil horizons for clay formation. This phenomenon is clearly defined in the lateritic soils of Garamba park in the Central Congo, which were studied by the author in 1952 (6).

In Ruanda-Urundi, black margalitic soils develop under special conditions (at the bottom of upland bogs and lakes) at an elevation of up to 1000 m in a dry climate characterized by limited annual precipitation (less than 1000 mm) and a pronounced dry season lasting 4 months (16, 17). These soils occur in conjunction with lateritic soils with a weakly pronounced humus horizon, saturated with bases. The aggregation of such a horizon leaves something to be desired, and, according to the observations of the author, on slopes exceeding 8% it is rapidly eroded and washed out.

With increasing elevation from 1000-1500 m conditions for humus formation become more favorable: the amount of annual precipitation increases to 1200-1300 mm, while the duration of the dry season decreases to 3 months. A well-defined, dark, base saturated, and aggregated humus horizon appears in ferri- and latersols. We call these soils humic mountain soils.

Beginning with an elevation of 1500 m and up to about 2000-2200 m, the humus content and the clarity of the humus horizon gradually increase as compared with the soils of the preceding zone (from 1000-1500 m), but the depth of humus penetration rises sharply. Soils are frequently encountered with a penetration depth of up to 150 cm and even 200 cm. The color of the humus is often masked by the color of the soil itself and it can only be determined by analysis. We call these soils humic high-mountain soils. In Ruanda-Urundi they develop at elevations between 1500 m and 1900-2000 m.

As Figures 1, 2, and 3 (5) show, the C:N ratio of the humus horizons, their pH, and the degree of base saturation of the soils differ little from those of Ruanda-Urundi soils located below 1500 m; their humus content, however increases constantly. With increasing elevation the climate becomes cooler and more humid, and clay forms more evenly along the soil profile. The difference in the amount of clay, which in valley soils increases regularly with depth under a climate with a well-defined dry season, disappears gradually starting with an elevation of 1500 m. The color of lateritic soils also begins to change: red and yellow soils acquire paler hues and shades. If below 1500 m elevation, latosols generally occupy larger areas than ferrisols, above 1500 m ferrisols predominate over latosols in Central Africa. This is associated with more dissected relief and a thinner weathering crust.

From 2000 m to 2300-2400 m elevation the humus content of soils increases greatly, reaching 20%-25% and more. The C:N ratio in these soils increases sharply and the pH and the base saturation of the humus horizons decreases. We call these soils high-mountains soils with a high humus content. Morphologically they are similar to humic high-mountain soils, but according to analytical data they are closer to the pseudo-humic high-mountain soils described earlier.

Together with the characteristic accumulation of humuc in Ruanda-Urundi, there is another pronounced characteristic of the vertical zonality of soils in Central Africa, the appearance, starting with 1900 m elevation, of hydromorphic soils with an extremely thick (120-150 cm), black humus horizon, of a very low specific gravity and very low base saturation. Their humus horizon contains on the average 10%-14% humus. The C:N ratio is higher than in high-mountain humic soils, which is an indication of the lesser degree of decomposition of organic substances. Such soils are confined to an extremely humic climate (more than 2000 mm) with constant rains and fog. They first appear in depressions in the lower part of slopes and everywhere where the microclimate promotes temporary excessive wetting. At an elevation of 2300-2400 m they occupy wider and wider areas and are found everywhere, including slopes up to 15%-20%.

Judging by the work of Thorp and Gay Smith (14, 15), these soils should be classified as Ando soils. But because of the sharp differences in the characteristics of Ando soils given by these authors and Segalen (12) who studied them in Madagascar, we prefer to leave the problem open and call them pseudo-humic high-mountain soils.

In addition to pseudo-humic soils there is another characteristic manifestation of the hydromorphism of the vertical zonality of soils in Central Africa starting at 2200 m elevation — the appearance of humic-peaty and peaty soils. As pseudo-humic soils, they first occupy only the lower parts of slopes, depressions, etc., then gradually they propagate to gently sloping areas, and, finally, starting at 2400 m they also develop on steep slopes.

All these manifestations of hydromorphism are associated with the extremely humic climatic conditions, with the large amount of precipitation, and most of all with the constantly high atmospheric humidity, which is maintained throughout the year by fog and drizzle. A peculiar type of vegetation — a high-mountain forest with a great number of woody ferns, mosses, and lichens, corresponds to this climate. The latter lend an unusual aspect to the landscape, covering the stems and branches of trees and hanging down in the form of long beards.

Sphagnum is found among the mosses, and a great amount of heather grows on acid, humic-peaty soils. Hagenia sp. and gigantic Lobeliaceae are characteristic among the other vegetation. At 2200 m elevation solid tickets of bamboo (Arundi-naria sp.) are found. According to the literature there must be a relationship between

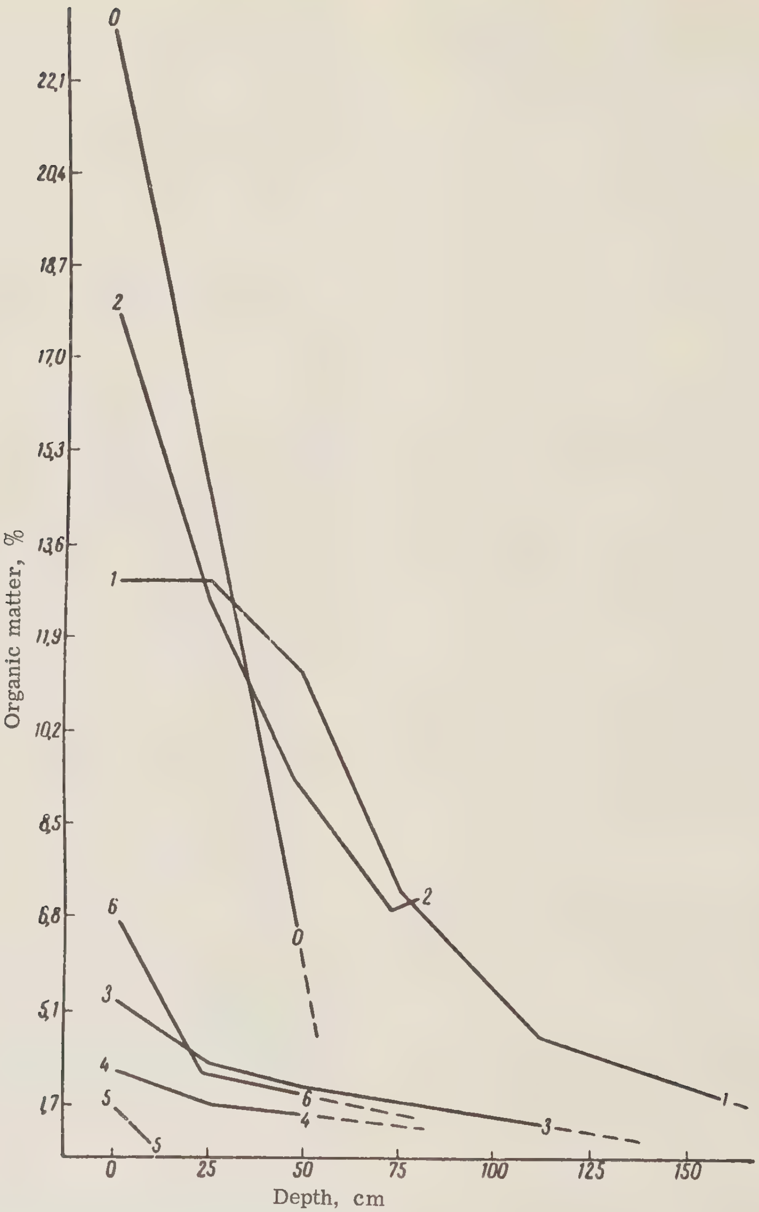

Fig. 1. - Distribution of organic matter in humus horizons. 0 - humic-peaty; 1 - pseudo-humic; 2 - high humus content; 3 - high-mountain humic; 4 - mountain humic; 5 - valley lateritic soils; 6 - black margalitic.

bamboo and Ando soils, but this is not confirmed by observations in Ruanda-Urundi.

All these hydromorphic soils extend to 3000-3500 m elevation, i.e., to the level at which climatic conditions become less humid.

The progressive clay accumulation with depth ceases in high-mountain soils above 2000 m and the reverse is often observed. The color of the soils also becomes less bright, and at 2200-2400 m soils with a grayish tint predominate. Ferrisols predominate more and more over latosols in dissected relief. Young tropical soils appear in greater numbers.

The characteristics of the humus horizons of mountain soils in Ruanda-Urundi shown in Figures 1 and 3 point to the progressive and considerable increase of the amount of organic matter in soils with a high humus content, in pseudo-humic soils, and in peaty-humic

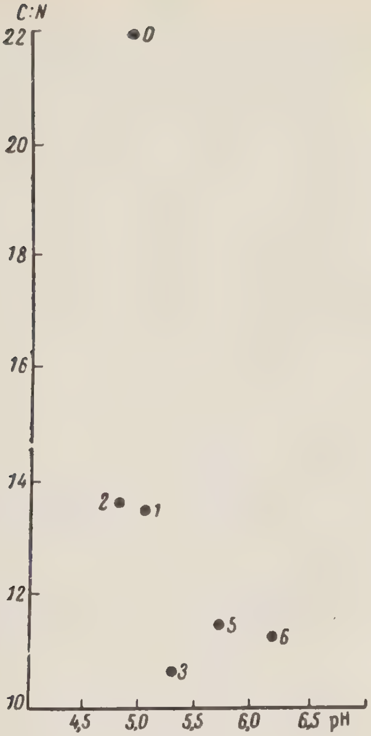

Fig. 2. - C:N ratio and pH of humus horizons.
(Symbols are the same as in Fig. 1).

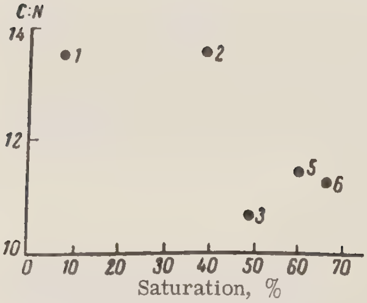

Fig. 3. - Relationship between the C:N ratio and the degree of base saturation of humus horizons.
(Symbols are the same as in Fig. 1).

soils, and also to the extremely low base saturation of pseudo-humic soils. The C:N ratio in the first two soils is higher than in mountain soils located below 2000 m, and reaches almost 14; as far as the peaty-humic soils are concerned this ratio exceeds 20.

It must be noted that if the characteristics of the humus horizons of the foregoing mountain soils point to large differences between the indices for ferrisols and latosols, in dark young soils, according to our investigations (5), the degree of pH saturation of the humus horizon is considerably higher than in the ferrisols and latosols of the same climatic zone, while the C:N ratio of dark young soil in Ruanda-Urundi does not exceed 8.0-8.5 (in ferrisols and latolsols it exceeds 10).

British soil scientists, after examining the data collected by them on the high-mountain soils of Kenya, Tanganyika, and Uganda, came to the conclusion (2) that the humus content of soils increases on the average by 0.8% with every 300 m increase in elevation in Central Africa and that an increase of 250 mm in annual precipitation results in an increase in the content of organic matter in the soil by 1.3%, whereby the increase is more rapid in fine-textured soils than in coarse-textured soils.

The same property of high-mountain soils in the tropics is pointed out by Dames (4) for the soils of Java and by Fridland (1) for soils of Northern Vietnam. Fridland also describes humic soils and soils with a high humus content, whereby his last profile is similar to our pseudo-humic soils in climatic conditions, humus content, the high C:N ratio, and the degree of saturation.

Plateaus and mountains in Ruanda-Urundi rarely exceed 3000 m elevation, except for several active or extinct volcanos, the slopes of which are mostly covered by young, poorly developed soils. On the highest mountains of Central Africa, such as Ruwenzori, Kenya and Kilimanjaro, alpine vegetation and shallow mountain-meadow soils rich in humus occurs at elevations from 300°-3500 m. Peat beds develop in depressions and hollows, gravelly soils on the surface of outcropping hard rocks, while the summits are relatively bare.

At 4300 m elevation near the snow line, Maréchal and Laruelle (9) found striated soils like those described by Cailleux for Greenland. Permanent snow begins at an elevation of 4700 m.

Our investigations of the high-mountain soils of Ruanda-Urundi show a clear succession in geographical location and alternation of various soil groups and their characteristics.

The vertical zonality of soils in Central Africa is characterized by:

a) a progressive increase of humus with height; and b) a progressive increase of hydromorphism with pseudo-humic soils appearing above 2000 m elevation and humic-peaty soils above 2200 m. The latter apparently extended to a height of 3000-3500 m, where shallow soils of the alpine vegetation belt begin. In addition to the foregoing high-mountain soils, podzols, podzolic soils, and brown earths are found in the mountains of Central Africa. But they never occupy large areas and are rather an exception.

We found high-mountain podzols at an elevation of 1750-2000 m, where they have developed only because of unusually favorable conditions, such as gravelly and acid parent material, ample precipitation, etc. These high-mountain podzols of Africa are characterized by a well-aggregated, thick A_1 horizon, whereas a well-defined A_1 horizon is lacking in the valley podzols of Central Africa (7, 8).

There is another characteristic of high-mountain soils in the black continent: an unusual dark horizon at a depth of 40-60 cm in the soils of Central Africa located between 1400-2400 m elevation. It is better developed in latosols on the flat summits of hills and in the lower parts of slopes than in ferrisols, in young soils, and on steep slopes. But this phenomenon is not equally pronounced everywhere, and the causes for the formation of the dark horizon are still unknown.

Received February 1, 1961

BIBLIOGRAPHY

1. FRIDLAND, V. M. 1959. Vertical zonality of soils in Northern Vietnam. Pochvovedeniye, No. 11.
2. BIRCH, H. F. and N. T. FRIEND. 1956. The organic matter and nitrogen status of East African soils. J. Soil Sci. No. 1.
3. BRAMMER, H. and A. S. ENDREDY. 1954. The tropical black earths of the Gold Coast and their associated glei soils. V Intern. Congr. Soil Sci. Leopoldville.
4. DAMES, T. W. G. 1955. The soils of East-Central Java, Bogor.
5. DENISOFF, I. 1959. Synthése des sols explorés au Ruanda-Urundi. Conférence d'Abidjan.
6. DENISOFF, I. 1956. Avec collaboration de Croegaert J. Les sols du Parc National de la Garamba. Mission de Saeger. Bruxelles.
7. DONIS, C. 1948. Note sur la podzolization au Mayombe. Conférence Africaine des Sols. Goma.
8. LENEUF, N. and R. OCHS. 1956. Les sols podzoliques du cordon littoral en basse Côte-d'Ivoire. VI Intern. Congr. Soil Sci. Paris.
9. MARÉCHAL, R. and J. LARUELLE. 1954. Les sols du graben centre-africain et les sols demontagne de la region du Ruwenzoi. V Congr. Intern. de la Science du Sol., Léopoldville.
10. MOHR, E. C. J. and F. A. VAN BAREN. 1954. Tropical Soils. The Hague.
11. OAKES, H. and J. THORP. 1950. Dark clay soils of warm regions. Soil Sci. Soc. America. Proc. No. 15.
12. SEGALEN, P. 1957. Etude des sols dérivés des roches volcaniques basiques à Madagascar. Mémoires de l'Institut Scientifique de Madagascar. Serie D, t, VIII.
13. SIMONSON. 1954. Morphology and classification of the regur soils of India. J. Soil Sci.
14. THORP, J. 1957. Report on a field study of soils of Australia. Adelaide.
15. THORP, J. and G. SMITH. 1949. Higher categories of soil classification: order, suborder and great soil groups. Soil Sci., February, v. 67.
16. VANDENPLAS, A. 1946. La température au Congo Belge. Bruxelles.
17. VANDENPLAS, A. 1948. Les pluies au Congo Belge. Bruxelles.

PROBLEM OF THE 'HYDROPHYSICAL' SOIL CONSTANTS

A. A. RODE

When studying the moisture regime of soils we use the so-called hydrophysical soil constants, which are also sometimes called the "water-physical constants" of soil. They characterize the moisture conditions of the soil. A great majority of them (let us call them WPC for short) are such soil moisture values (expressed in percentages by weight or volume of soil) during the transition through which soil moisture properties (amounts), in particular its mobility, change more or less sharply.

By comparing observed moisture with the WPC we can judge the quality of moisture in the soil — its mobility, availability to plants, etc.

The water-physical constants of soil are:

1. Total moisture capacity (TM)
2. Minimum moisture capacity (MM)
3. Discontinuous capillary moisture (DCM)
4. Permanent wilting moisture (PWM)
5. Maximum hygroscopicity (MH)
6. Maximum adsorption moisture capacity (MAM)

The concept "physical constants" is used in physics. Such constants are: the specific gravity, specific heat capacity, specific electrical conductivity, etc. of various substances. These values, being measureable under specific conditions, are actual constants, i. e., fixed. Variations in their individual values depend only on the accuracy of the measuring instruments.

The matter is quite different as far as the water-physical "constants" of soils are concerned. Because of their nature these values cannot be true constants, i. e., fixed values. Their variability depends on a number of factors.

First of all, the soil is a substance the composition and properties of which change constantly. It becomes moist and dries out; the soil colloids peptize and flocculate; plant roots develop and die out; organic substances synthesize and decompose, etc. All these and many other processes result in a change in soil properties with time, including its water-physical constants.

Secondly, as we know, soil is spatially heterogeneous, and one and the same property, measured in a number of neighboring points, will necessarily have differing quantitative values.

Thirdly, changes in moisture mobility, corresponding to varying WPC, almost never occur "by jumps" in the true meaning of the word. They are never represented on a graph by a break in the straight line, but always by a section of a curve, no matter how small. In other words there is always a transition area, no matter how narrow, in which the mobility of moisture changes more rapidly, but still smoothly.

These three main factors, as well as others result in that the WPC of soils are not some definite, constant values for a given soil layer. The following methodological conclusion follows from this: the WPC of soils should not be characterized by one value, as was done before, but by a moisture interval within which the given WPC can vary. This interval must be as narrow as possible, but its width should not be set arbitrarily — must issue from the analysis of variations of the values sought.

Let us illustrate the foregoing by concrete examples, whereby we will limit ourselves to the most important: WPC, MM, and PWM.

As basic material let us use the results of moisture observations of dark soil in the large depression at the Dzhanybek station (West Kazakhstan Oblast') of the Academy of Sciences of the USSR. The observations were made under our supervision by the scientist M. N. Pol'skiy.

To examine the problem of the wilting moisture as a water-physical constant, let us use the results of observations on the moisture of dark soil under a pure stand of Chinese elm. Let us explain that we will not speak of the WM as determined by the method of reduced-scale pot experiments (shoots), but of that residual soil moisture which is found under field conditions in early or mid-summer as a result of the complete exhaustion of all available moisture by plants. The WM thus determined, as a comparison showed, is very close to the WM determined by reduced-scale pot experiments, differing from it only by 1-2 tenths of a percent of the dry soil weight. At the same time this residual moisture value is free of that subjectivity which is associated with the determination of the beginning of wilting in reduced-scale pot experiments. This ultimate residual moisture actually characterizes the content of that part of the moisture which remains unavailable to given plants under field conditions.

The observations embrace the period from June 3, 1952, to September 24, 1957. There are altogether 44 periods of observation. In 1952 the depression was filled with meltwater, which caused the rise of ground water to a depth of less than 2 m. The same was repeated in 1953. After this there was a 3-year period, until the spring of 1956, during which the depression was not flooded, and spring wetting was limited to the first meter of the soil. In the springs of 1956 and 1957 complete wetting took place again, but it was not as excessive as in 1952.

The pure stand of Chinese elm was started in 1951, it developed successfully, with the roots reaching a depth of 190 cm in 1952 and 370 cm in 1955. In 1953 the elm plants were able to use the moisture from the capillary fringe of ground water.

Table 1 gives the moisture contents for every half meter to a depth of 400 cm, i. e., to the maximum depth of lowering of the upper boundary of the capillary fringe. Let us analyze these data, except for the first half meter, the drying of which was caused for a great part by evaporation. In all the remaining layers we see the same picture. The high moisture content decreased with time from the spring of 1952 to reach a certain ultimate minimum value, after which the progressive drop of moisture ceased and a period set in during which it fluctuated somewhat in one or the other direction from a certain average. The moisture content corresponding to these periods is shown by individual braces. These periods begin at different times in the various layers. This phenomenon did not take place at all in the 350-400 cm layer, which was always, if only partly, in the capillary fringe. The differences in the dates of the onset of permanent minimum moisture (the deeper the later) are attributable to the gradual deepening of the roots of the growing elms and their gradual propagation in the soil.

Periods of constant minimum moisture ended in all layers in the spring of 1956 after renewed complete wetting and in the 300-350 cm layer in autumn 1955 as a result of soil wetting from below. In the 50-100 cm layer the period of minimum moisture was also interrupted in the spring of 1954 and 1955 as a result of the partial wetting of this layer by meltwater, and minimum moisture was restored by July. In the 150-200 cm layer this period ended in early 1954, and in the 200-250 cm layer in the spring of 1955 as a result of the wetting of the soil from below.

During the course of many months and even 3 years the ultimate minimum moisture remained constant. This indicates that this value actually characterizes the amount of moisture unavailable to plants. As can be seen from Table 1 these values fluctuate noticeably. Table 2 gives the minimum, maximum, and average data for this value.

Let us note that the minimum ultimate moisture in the 150-200 cm layer was reached by the end of the summer of 1953 (94-99 mm), and in the 250-300 cm layer at the end of the summer of 1954 (95 mm), but then the dry layer was moistened from below in both cases. We can see from these data that the WM (conditionally taken as the constant minimum moisture) varies noticeably. The amplitude of the variations averages about 10% or ±5% of the average value.

A careful analysis of Table 1 shows that ultimate moisture values were constant again in various layers after the spring of 1956, being, however, slightly higher than those given in Table 2.

Layers, cm	1956	1957
50-100	108-105 mm	105-104 mm
100-150	109- 98 "	96 "
150-200	105-100 "	106-101 "
200-250	107 "	101-100 "
250-300	107 "	106 "

Consequently, in years with more ample soil wetting plants leave a certain amount of non-readily available moisture in the soil which they utilize in drier years. This phenomenon is also one of the causes of the variability of the WM. The foregoing referred to layers 0.5 m thick.

Let us examine the variation of moisture in layers 10 cm thick. Let us not do it for the entire 4 m layer to which Table 1 refers, but for the layer from 100-150 cm deep for which we have the longest period of constant minimum moisture which was not interrupted by spring wetting. Table 3 gives the data for this layer. We can see again that minimum moisture was constant in all the 10 cm layers during the period from August 10, 1953 to March 27, 1956, fluctuating around a certain average value. Table 4 characterizes the magnitude of these fluctuations.

As we can see, the amplitude of these fluctuations here is higher than for the 0.5 m layers: 13%-16% from the average. This is attributable to the fact that there is a certain mutual compensation of deviations of varying signs when calculating the moisture content for 0.5 m layers.

The foregoing data prove the point made earlier that the wilting moisture of any layer of a given soil cannot be characterized by only one value, but must be characterized by a certain interval of values. We saw examples of such intervals in Tables 3 and 4.

Now let us examine similar material for minimum moisture capacity. We will use observations made on the moisture regime of

Table 1

Moisture content in dark chernozem-like soil of a large depression under a pure stand of Chinese elm, mm of the water

Date	Half-meter layers, cm								Ground water	
	0—50	50—100	100—150	150—200	200—250	250—300	300—350	350—400	Date	Depths, cm
June 3, 1952	161	155	145	164	169	178	—	—	June 3	290
July 16	98	124	127	150	160	168	181	—	July 16	357
Sept. 3	98	112	107	142	162	170	182	190	Sept. 3	411
Oct. 10	89	108	103	138	162	163	168	183		
Mar. 24, 1953	119	112	123	146	154	158	166	173	Mar. 24	515
May 4	164	163	151	162	174	193	—	—	May 4	261
June 30	90	117	111	138	156	165	174	186	July 8	437
Aug. 10	96	103	92	109	130	152	169	177	Aug. 10	485
Sept. 25	83	105	89	94	106	137	158	171		
Oct. 24	91	104	92	99	120	149	162	175		
Mar. 15, 1954	123	108	96	109	136	151	161	178	Mar. 29	152
May 7	153	122	88	109	130	144	156	179	May 8	528
June 1	101	110	89	107	127	145	160	178	May 31	533
July 20	78	103	88	93	92	114	142	167	July 20	583
Aug. 16	88	100	90	94	92	102	142	165	Aug. 20	604
Sept. 21	79	102	87	91	89	95	126	160	Sept. 21	620
Nov. 19	128	103	92	96	95	110	145	174	Dec. 1	592
Dec. 25	139	105	88	95	93	120	150	168	Dec. 31	589
Jan. 26, 1955	144	101	89	93	93	126	148	168	Jan. 31	590
Feb. 26	150	103	87	92	97	125	149	181	Mar. 7	589
April 19	137	116	85	93	100	130	147	147	April 22	576
May 24	118	128	91	92	101	122	142	153	May 30	606
June 15	91	101	85	91	93	101	114	143	June 21	626
July 8	85	103	86	90	91	92	97	134	July 16	644
Aug. 16	78	95	85	91	91	89	94	137	Aug. 23	652
Sept. 14	85	106	89	94	93	94	97	115	Sept. 14	658
Oct. 15	85	99	84	90	90	88	94	136	Oct. 12	652
Jan. 6, 1956	96	102	87	92	92	94	113	141	Jan. 11	632
Feb. 3	116	100	89	94	91	91	122	141	Feb. 10	630
Feb. 28	107	101	89	93	92	93	126	142		
Mar. 27	101	104	89	93	92	97	128	140	Mar. 10	630
May 15	175	157	150	172	173	175	184	202	May 21	361
June 11	147	147	142	158	162	169	177	187	June 21	467
July 10	107	131	111	116	128	142	160	181	July 16	537
Aug. 8	102	112	106	109	117	136	154	174	Aug. 1	561
Sept. 5	92	105	99	104	107	121	139	152	Sept. 8	616
Oct. 13	108	108	98	104	107	116	135	156	Oct. 8	611
Jan. 21, 1957	188	150	109	105	113	131	143	163	Jan. 11	600
Feb. 18	172	138	98	100	110	126	137	156	Feb. 11	602
May 3	158	149	140	166	175	182	187	—	May 7	304
June 28	106	115	110	120	132	142	157	171	July 1	549
July 26	98	112	103	106	110	125	135	161	July 26	602
Aug. 26	94	105	96	102	101	106	124	147	Aug. 30	642
Sept. 24	101	104	96	101	100	106	119	144	Sept. 20	658

the same dark soil in the same large depression, but in an area kept under clean fallow for many years. The plot was set up in 1951 and since then was kept completely free of weeds. In 1952 and 1953 the depression was flooded with meltwater, as a result of which the soil layer was wetted throughout and the ground water rose substantially. In 1954, 1955, and 1956 only surface wetting occurred to a depth of not more than 150 cm. The ground water rose slightly in 1954, insignificantly in 1955, and almost by 1 m in 1956. But this rising occurred not as a result of the complete wetting of the area under clean fallow, but as a result of the lateral recharge of ground water from other points in the same depression where snow accumulated and where complete wetting occurred followed by the spreading of ground water. As a result we have a 3-year period (from the spring of 1953 to the spring of 1956)

Table 2
Ultimate minimum moisture in each half-meter layer, mm of the water

Layer, cm	No. of observations	Maximum	Minimum	Amplitude	Average	Amplitude % of average
50—100	19	106	95	11	102	11
100—150	24	96	84	12	89	13
150—200	18	96	90	6	93	6
200—250	16	97	89	8	92	9
250—300	8	97	88	9	92	10
300—350	4	97	94	3	95	3

Table 3
Moisture content of dark soil in a large depression under a pure stand of Chinese elm at depths from 100-150 cm, % of soil volume

Date	10-cm layers				
	100—110	110—120	120—130	130—140	140—150
June 3, 1952	28,6	29,0	27,6	28,5	30,9
July 16	23,4	24,7	25,2	26,2	27,1
Sept. 3	20,1	20,6	20,9	20,7	24,4
Oct. 10	20,2	20,4	20,2	21,2	21,0
Mar. 24, 1953	22,5	23,4	24,7	25,1	26,6
May 4	30,3	30,0	30,1	30,2	30,1
June 30	21,4	22,4	21,1	22,5	23,8
July 10	18,6	18,7	17,9	17,9	18,5
Sept. 25	17,8	18,2	17,8	17,3	18,2
Oct. 24	18,2	18,5	18,2	18,7	18,2
Mar. 15, 1954	19,2	19,7	18,6	18,9	19,7
May 7	16,9	18,2	17,7	17,3	17,6
June 1	17,7	18,0	17,4	17,3	18,9
July 20	17,4	17,6	17,3	17,1	18,2
Aug. 16	17,8	18,1	18,3	17,5	18,1
Sept. 21	17,4	17,5	17,8	17,1	17,5
Nov. 19	18,8	18,5	18,8	17,8	18,1
Dec. 25	17,7	17,7	17,2	17,3	17,7
Jan. 26, 1955	17,7	17,7	17,9	17,8	17,7
Feb. 26	16,8	17,7	16,9	17,4	18,6
April 19	16,4	17,2	17,2	17,1	17,5
May 24	18,2	18,5	17,8	17,8	18,7
June 15	16,9	17,2	16,8	16,6	17,3
July 8	17,7	17,6	16,8	16,5	17,7
Aug. 16	16,9	17,3	16,9	16,6	17,5
Sept. 14	17,8	18,1	17,2	18,3	17,7
Oct. 15	16,8	17,2	16,5	16,5	17,3
Jan. 6, 1956	17,8	17,5	16,9	17,0	17,7
Feb. 3	17,7	18,0	17,8	17,8	17,6
Feb. 28	17,8	18,0	17,7	17,3	18,0
Mar. 27	17,8	17,7	17,7	17,8	18,1
May 15	30,8	30,2	29,5	29,1	30,8
June 11	28,4	28,5	27,8	28,4	29,0
July 10	22,8	22,9	22,1	21,4	21,9
Aug. 8	20,6	21,8	20,8	21,1	21,9
Sept. 5	20,2	20,0	19,6	19,3	20,0
Oct. 13	19,8	19,9	19,2	19,1	20,0
Jan. 21, 1957	25,2	23,1	20,6	19,9	20,0
Feb. 18	21,2	19,5	19,6	19,1	19,6
May 3	28,0	28,8	27,9	27,0	28,6
July 28	22,0	22,0	21,6	21,7	22,4
July 26	21,4	20,7	20,4	20,2	20,8
Aug. 26	19,1	19,1	19,3	18,9	19,5
Sept. 24	19,3	19,7	19,1	18,5	19,5

Note: Comma represents decimal point.

Table 4

Maximum, minimum, and average constant ultimate minimum moisture for every 10 cm layer, % of soil volume

Layer, cm	Maximum	Minimum	Amplitude	Average	Amplitude, % of average
100—110	19,2	16,4	2,8	17,7	16
110—120	19,7	17,2	2,5	17,6	14
120—130	18,8	16,5	2,3	17,5	13
130—140	18,9	16,5	2,4	17,4	14
140—150	19,7	17,3	2,4	18,0	13

Note: Comma represents decimal point.

in which the ground-water level dropped steadily in the clean fallow area under soil which was previously wetter throughout. This drop was caused alone by the outflow of water from the depression into the surrounding plain. This period even lasted almost 4 years in the 4th, 5th, and 6th half-meter layers, since surface wetting on the one hand, and the rise of ground water resulting from lateral inflow in 1956, on the other hand, did not affect the moisture of these layers. With this, ideal conditions were created for the study of the behavior of moisture during a long time in the soil layer above the capillary fringe with a moisture corresponding to the mimimum moisture capacity. The thickness of this layer increased gradually as the ground water drained and its level and the upper boundary of the capillary fringe, associated with it, dropped.

Table 5 gives the moisture content of every 0.5 m layer from the beginning of 1952 to the end of 1956. It does not include the layer from 0-50 cm, which is subject to annual physical drying and the layers below 3 m which where partially or fully located within the limits of the capillary fringe throughout the entire period.

Figure 1 and Table 5 show that the moisture content in each 0.5 m layer progressively decreased at the beginning as gravity water drained and the ground-water level dropped (Fig. 1, F). But a period occurred in each layer when the moisture content ceased to decrease progressively and was replaced by a period when the water content became more or less constant with only slight fluctuations in one or the other direction. The deeper the layer, the later the foregoing period occurred, since the gravity water of the capillary fringe drained later. In layers below 150 cm the period of constant moisture (with variations within certain narrow limits) lasted until the end of 1956, while in layers from 50-100 cm and from 100-150 m it ended in the spring of 1956 because of wetting by surface water.

In order to reveal the period with a constant moisture and its limits move clearly, we resort to a method of calculating sliding averages of 5 neighboring observed values. The path of sliding averages is verified from the beginning with several moments of progressive changing moisture content in all half-meter layers which actually ceases and changes with periods of slight fluctuations. The period in Figure 1 is separated with square brackets.

The moisture contents, corresponding to this period, must be considered as characteristic of minimum moisture capacity, i. e., that maximum amount of moisture which is retained by the soil after all gravitational water has drained. The data for these periods are indicated by braces in Table 5.

Table 6 shows, first of all, that the average moisture content corresponding to the MM in all 0.5 m layers, except for that from 100-150 cm, is the same, varying from 144-148 mm. The 100-150 cm layer has a noticeably lower moisture content, averaging 132 mm. In the soil profile this layer corresponds to the horizon with the maximum concentration of carbonates.

To show conclusively that the moisture corresponding to the MM in each of the half-meter layers studied is really constant, we calculated the average moisture contents during the periods with constant moisture for 1954 and 1955. For the layer from 200-250 cm, in which the period of constant moisture began only in July 1954, we made the calculations for 1955 and 1956. The results of the calculations are given in Table 7. From it we can see that the average moisture contents in the half-meter layers within the layer with constant moisture were the same in the 2 consecutive years, differing from each other by not more than 1 mm. This difference is considerably smaller than a possible error in the determination. At the same time the moisture content of the layers from 200-250 cm and from 250-300 cm, which were partially (first)or fully (second) within the limits of the dropping capillary fringe, changed by 3 mm in the first case and by 5 mm in the second.

Thus we come to a very important conclusion.

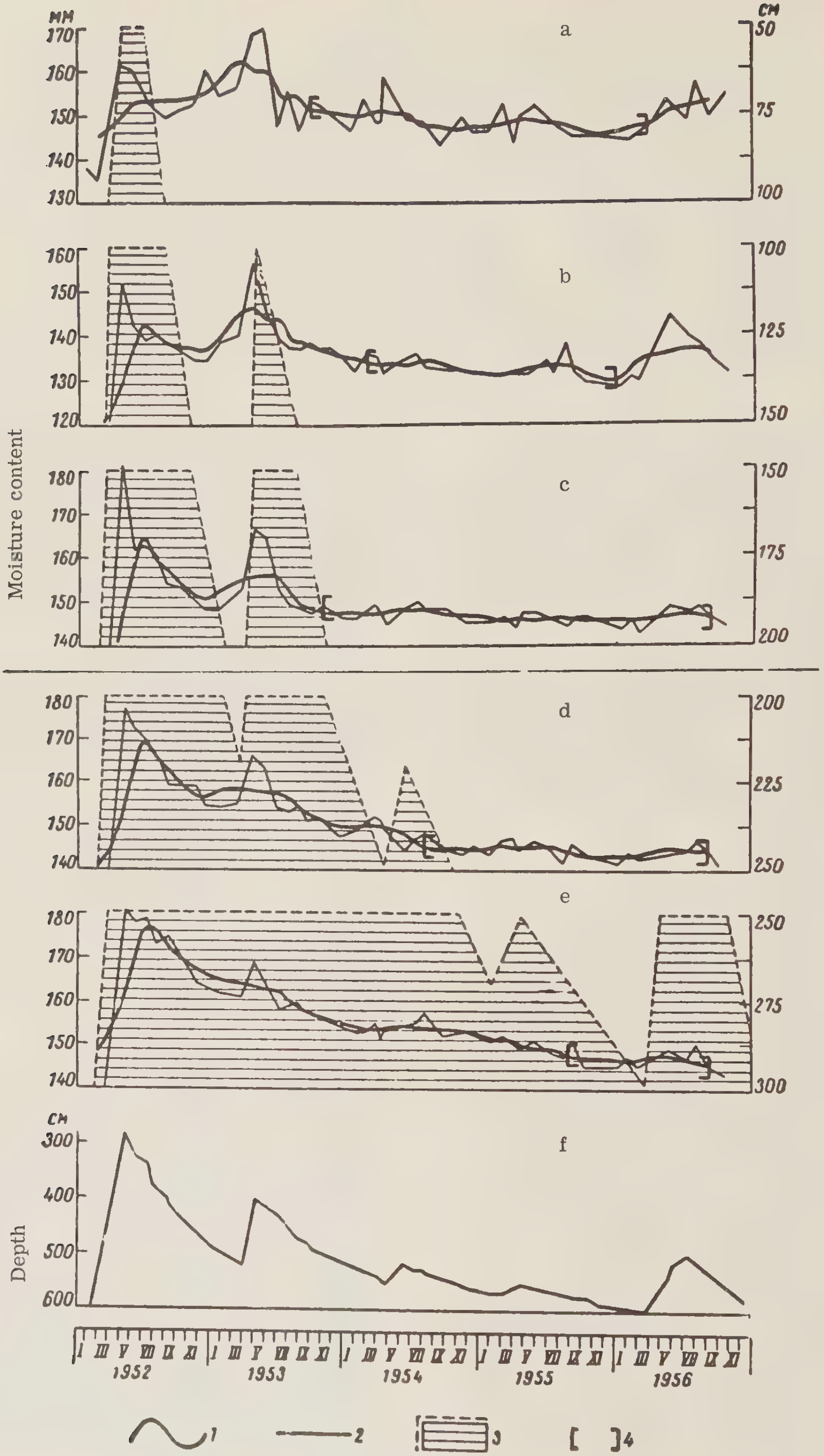

Fig. 1. - Change in the moisture content in half-meter layers of dark soil in a large depression under old clean fallow.
1 - moving moisture content averages from 5 neighboring determinations; 2 - observed moisture contents; 3 - periods and depths of the capillary fringe; 4 - limits showing the sections of curves

(Continued next page top)

with constant moisture content values corresponding to the minimum moisture capacity. Layers, cm: a - 50-100; b - 100-150; c - 150-200; d - 200-250; e - 250-300; f - ground-water level.

Table 5

Moisture content of dark soil in a large depression under old pure fallow, mm of the water layer

Date	Half-meter layers, cm				
	50—100	100—150	150—200	200—250	250—300
Jan. 28, 1952	138	103	108	123	132
Feb. 27	135	102	107	118	130
May 2	161	152	182	177	181
June 3	160	142	162	172	178
July 1	155	139	163	170	179
Aug. 1	151	140	161	166	173
Sept. 2	149	139	154	159	175
Oct. 8	151	136	153	159	169
Nov. 19	152	134	150	159	164
Dec. 19	160	134	148	154	163
Jan. 23, 1953	154	138	148	154	162
Mar. 19	157	140	152	155	161
April 26	168	156	166	166	169
May 27	169	145	159	163	164
July 1	147	139	153	154	158
July 30	155	137	149	153	159
Aug. 31	146	137	148	155	159
Sept. 24	153	138	147	151	157
Oct. 23	152	137	149	152	156
Nov. 20	150	137	148	150	155
Dec. 23	148	135	146	147	154
Jan. 26, 1954	146	132	146	148	153
Feb. 24	153	136	148	150	153
Mar. 23	148	135	149	152	155
April 12	148	131	146	151	152
April 19	158	132	145	149	153
June 14	149	135	149	144	154
July 12	148	136	150	147	155
Aug. 3	148	133	148	148	157
Sept. 24	143	132	148	144	152
Nov. 18	149	132	145	143	153
Dec. 20	146	131	145	145	152
Jan. 29, 1955	146	131	145	143	151
Mar. 4	152	131	146	146	152
April 4	143	131	144	147	150
April 21	149	132	147	144	149
May 28	152	134	147	146	151
July 15	148	131	145	144	148
Aug. 18	146	138	144	141	147
Sept. 12	145	131	146	145	151
Oct. 12	144	128	143	141	145
Jan. 9, 1956	144	128	143	141	145
Feb. 9	144	130	145	143	147
Mar. 1	147	129	142	142	145
May 21	153	144	148	143	149
July 14	148	139	147	144	147
Aug. 6	157	138	148	146	150
Sept. 10	149	134	145	144	145
Oct. 24	154	131	143	139	143

Table 6

Maximum, minimum, and average moisture contents corresponding to the MM in every half-meter layer, mm of water

Layer, cm	No. of determinations	Maximum	Minimum	Amplitude	Average	Amplitude, % of average
50—100	27	158	143	15	148	10
100—150	23	138	128	10	132	8
150—200	31	150	142	8	146	6
200—250	22	148	139	9	144	6
250—300	12	151	143	8	147	5

Table 7

Moisture content of half-meter layers under old clean fallow, mm of the water

Layer, cm	Aver. annual moist. cont.		
	1954	1955	1956
50—100	149	148	—
100—150	133	132	—
150—200	146	146	145
200—250	147	144	143
250—300	154	149	—

In the case when a soil layer, which is wetted to a moisture corresponding to the MM, is immediately underlain by the capillary fringe, i. e., in the absence of drier soil with a higher suction force under the layer, the average moisture content in the wetted layer remains not only "practically" (in the expression of S. I. Dolgov), but actually constant for years. Sorption and capillary forces which retain the moisture in the soil apparently completely compensate for the effect of gravity on the moisture.

The constancy of moisture in the wetted soil layer (with variations within certain limits) permits us to say that this moisture characterizes the "true" MM, which corresponds to the actual complete drainage of gravitational water. As we know, when the MM is determined by the usual method of flooding, the greatest difficulty lies in the uncertainty of the time interval after flooding at which the MM should be determined, which leads to the uncertainty as to its value. There is no uncertainty in the MM values obtained by us, however.

Does the constancy of the moisture in the wetted layer mean that the moisture in it is immobile? We have no direct data to answer this question. But we assume that the answer to that must be in the negative. There is always a temperature gradient in the soil, the magnitude and sign of which change in the course of the year (and in the upper 46 cm of the soil in the course of the day). The presence of such a gradient necessarily results in the movement of moisture in the vapor state, whereby this moisture can change into the liquid state under corresponding conditions. Moreover, the temperature changes themselves, which vary in magnitude and often in sign in the various layers, result in a change in surface tension, which also should cause moist movement, but in the liquid state. Therefore, the constancy of the moisture content in a layer wetted to a moisture corresponding to the MM does not preclude the movement of moisture. It only serves as an evidence that the movements of moisture in opposite directions compensate each other in the course of a year.

Now let us return to Table 6. The table shows that the MM, as the WM, varies somewhat. The amplitude of its fluctuations in our case varies from 5% to 10% of the value, i. e., from ±2.5% to ±5.0%. Let us see what these fluctuations are in 10 cm layers, and let us analyze the values for the 150-200 m layer, for which we have the longest series of data. This is done in Table 8, the results of which confirm the foregoing conclusion that the MM fluctuates somewhat. In this case the amplitude of the fluctuations reaches 8%-12% of the values, i. e., from ±4% to ±6%.

Thus we can see that both the wilting moisture and the minimum moisture capacity fluctuate noticeably and therefore must be characterized not by a single value, but by a certain moisture interval. The same can be said of all other WPC.

In order to be able to apply this conclusion to other soil groups, we present data for thick chernozem (Table 9), for sod-podzolic soil under a mixed spruce stand, and for plowed sod-podzolic soil (Table 10).[1] The data in these tables fully confirm the foregoing conclusion made on the basis of material for dark soils in a large depression. These data also show

---

[1] The tables were compiled from unpublished data of A. F. Bol'shakov, to whom the author is grateful for allowing him to use this material.

Table 8

Fluctuations of the minimum moisture capacity of dark soil in a large depression, % of soil volume

Date	Depths of the 10 cm layers				
	150—160	160—170	170—180	180—190	190—200
Oct. 23, 1953	29,3	29,7	29,7	30,1	30,1
Nov. 20	29,8	29,2	29,1	29,6	30,1
Dec. 23	28,6	29,2	29,2	29,3	29,7
Jan. 26, 1954	28,8	29,2	29,2	29,7	29.1
Feb. 24	29,1	28,8	29,7	30,3	30,1
Mar. 23	29,1	29,3	29,8	29,6	31,2
April 12	28,2	28,6	29,1	29,8	30,1
April 19	28,6	28,3	29,2	29,2	29,6
June 14	29,2	29,2	30,2	31,2	29,7
July 12	29,7	30,7	30,2	29,7	30,2
Aug. 3	28,7	29,7	30,7	29,2	30,2
Sept. 24	29,2	30,1	29,8	28,8	29,7
Nov. 18	28,6	29,2	29,3	29,3	29,1
Dec. 20	28,7	29,1	29,6	29,1	28,7
Jan. 29, 1955	28,7	28,8	29,1	29,2	29,7
Mar. 4	28,2	29,0	29,2	30,2	29,9
April 4	28,4	28,4	28,8	29,2	29,7
April 21	28,2	28,8	28,4	29,5	31,7
May 28	29,1	28,8	29,6	29,6	29,8
July 15	28,3	28,7	29,2	29,2	29,2
Aug. 18	27,1	29,1	29,2	30,1	28,6
Sept. 12	28,3	29,1	29,1	29,2	30,1
Oct. 12	28,6	28,3	29,6	29,8	29,7
Jan. 9, 1956	27,7	28,2	28,3	29,2	29,2
Feb. 9	29,1	29,6	28,8	28,3	29,2
Mar. 1	28,1	28,7	28,8	28,7	28,1
May 21	30,2	30,0	29,2	29,8	28,7
July 14	29,8	29,5	29,4	29,4	29,4
Aug. 6	29,5	29,2	29,5	29,8	30,0
Sept. 10	29,0	28,7	29,0	29,4	28,7
Oct. 24	29,1	28,3	28,6	28,7	28,6
Average	28,8	29,1	29,3	29,4	29,5
Maximum	30,2	30,7	30,2	31,2	31,7
Minimum	27,1	28,2	28,3	28,2	28,2
Amplitude	3,1	2,5	1,9	3,0	3,5
Amplitude, % of average	11	9	8	10	12

Note: Comma represents decimal point.

that the moisture intervals which characterize the WM and MM may differ greatly, from ±3% to ±10% and even more.

How should these intervals be established?

The most correct way is to analyze a long series of data on soil moisture, examples of which we have shown earlier. Let us specify that in order to do that we do not always need such a long series as we have used. A 3-year and even a 2-year series is often sufficient. In the absence of even such a short series of data, as at the beginning of work at a new point, a rougher method would be to use an interval of ±5% from the average WPC found one or the other way. As moisture data are collected, this interval, as well as the average WPC, must be corrected by means of the analysis of these data. Let us note that the characterization of the WPC by a moisture interval has another important advantage. When we use a certain single value, we will rarely find a soil moisture which will correspond to the given WPC,

Table 9

Moisture content corresponding to the MM and WM (ultimate residual moisture) in thick chernozems, mm of water. Date of A. F. Bol'shakov

Indices	Depths of half-meter layers, cm				
	0–50	50–100	100–150	150–200	200–250
Minimum moisture capacity under a forest					
No. of determinations	21	31	13	17	11
Maximum	228	192	160	165	159
Minimum	200	166	150	155	141
Amplitude	28	26	10	10	18
Average	214	172	155	160	148
Amplitude, % of average	13	15	6	6	12
Minimum moisture capacity in the steppe					
No. of determinations	11	18	22	33	33
Maximum	219	170	161	163	139
Minimum	199	154	144	150	125
Amplitude	20	16	17	13	14
Average	205	163	153	155	131
Amplitude, % of average	10	10	11	8	11
Wilting moisture (residual moisture) under a forest					
No. of determinations	—	27	66	11	70
Maximum	—	103	107	105	100
Minimum	—	90	94	95	73
Amplitude	—	13	13	10	27
Average	—	96	100	100	90
Amplitude, % of average	—	14	13	10	30
Wilting moisture (residual moisture) in the steppe					
No. of determinations	11	24	14	—	—
Maximum	94	93	103	—	—
Minimum	83	82	92	—	—
Amplitude	11	11	11	—	—
Average	88	87	98	—	—
Amplitude, % of average	12	13	11	—	—

because of the fluctuations of this value. For instance, we found only once (January 26, 1954) in 30 cases that the moisture in the layer from 150-160 cm (Table 8) with an average MM of 28.8% corresponded to the MM. In the rest of the 30 cases it was either higher or lower than this value. Actually, however, it corresponded to the MM during the entire 3-year period, a fact that we can discover if we use a moisture interval to characterize this WPC.

Now the question arises whether the average WPC values are still of any importance. The answer is yes for such cases when we must compare the WPC of various soils of various layers of one and the same soil. Moreover, the average WPC values are required in various types of soil hydrological calculations, for instance, when determining the content of available moisture, the degree of moisture availability, the moisture deficit, etc.

Conclusions

1. The analysis of long-period data on the moisture of several soils of various groups showed that the water-physical constants (WPC) of soil fluctuate noticeably. Therefore we propose to characterize the WPC values by a moisture interval rather than a certain definite value. The width of the interval must be determined from the analysis of long-period moisture data. If this is impossible because of the lack

Table 10

Moisture content corresponding to the minimum moisture capacity layer by layer, % of soil volume. Data of I. S. Vasil'yev (1950)

Layer,cm	No. of determinations	Maximum	Minimum	Amplitude	Average	Amplitude, % of average
Sod-podzolic soil under mixed spruce						
0—4	16	2,0	1,8	0,2	2,0	10
4—9	18	35,4	29,2	6,2	32,4	19
9—16	23	36,5	30,8	5,7	34,0	17
16—25	24	34,7	29,9	4,8	31,9	15
25—35	17	35,0	29,4	5,6	32,3	17
35—45	22	35,1	29,2	5,9	31,9	18
45—55	21	34,7	29,6	5,1	32,0	16
55—65	19	35,8	30,1	5,7	32,7	17
65—75	15	34,7	29,5	5,2	32,4	16
75—95	11	34,0	30,2	3,8	31,9	12
Plowed sod-podzolic soil						
5—18	8	29,2	26,4	2,8	27,4	10
18—25	7	39,0	35,6	3,4	37,7	9
30—40	8	33,4	29,0	4,4	30,8	14
40—50	10	33,6	30,0	3,6	31,7	11
50—60	9	34,0	29,0	5,0	31,7	16
60—70	17	35,2	29,0	6,2	32,0	19
70—80	15	34,2	30,7	3,5	32,6	11
80—90	14	35,7	32,0	3,7	33,6	11
90—100	9	32,6	27,7	4,9	30,3	16

Note: Comma represents decimal point.

material, the width of the interval can be approximated as ±5% of the average WPC value.

2. The average WPC values retain their importance when comparing the WPC of various soils or various layers of the same soil, and also in soil hydrological calcualtions.

3. The moisture content of a soil layer subject to complete wetting and lying above the capillary fringe (independent of its thickness) characterizes the minimum moisture capacity of the given layer; it remains constant with only slight fluctuations in one or the other direction for several years. This indicates that the "true" value of minimum moisture capacity, as characterized by this moisture, is not only "practically," but also an actually constant value, varying only within certain limits.

4. The constancy of the moisture content in the layer in which it corresponds to the MM is no proof of the immobility of the moisture in it; it undoubtedly continues to move, but in such a way that its movements in various directions (probably primarily in the vapor state) mutually compensate each other.

EFFECT OF MAGNESIUM FERTILIZERS ON SANDY LOAM SOD-PODZOLIC SOIL

V. S. RUBANOV, Academy of Agricultural Sciences, Belorussian SSR

Magnesium plays an important role in the life of plants; it forms part of the molecular chlorophyll, takes part in photosynthesis and other biochemical processes, and affects the development of generative organs and fruit formation. Magnesium affects the yield of grain to a greater extent than the yield of straw, and the yield of roots and tubers in root and tuber crops (5).

More attention is now being paid in the agricultural literature to magnesium as a nutrient because of the discovery of its deficiency for plants on coarsely-textured sandy and sandy loam soils (5, 6, 7, 10). Certain foreign authors (13) call magnesium the fifth element among the most important elements lacking to plants in the soil. Kolings (4) notes that the deficiency in magnesium is especially pronounced during wet years in the United States under most varied soil conditions, most often in strongly leached sandy soils. Ample potassium fertilization may enhance magnesium deficiency, or cause it. Kolings explains this by the physiological antagonism between the foregoing elements and partly by intensified leaching as a result of an ample application of potassium salts. Nitrogen and phosphorous fertilizers improve the availability of magnesium in the soil. On the basis of experiments in water cultures Scharrer and Mengel (14) came to the conclusion that the one-sided increase of potassium nutrition leads to a physiological antagonism between potassium and magnesium, even though this antagonism manifests itself differently in individual crops (for instance, sunflower possesses a better ability to take up magnesium, than corn, while the opposite is true for potassium). According to the investigations of Mazayeva (10), short-day plants are more sensitive to a magnesium deficiency than long-day plants. K. P. Magnitskiy (5) found that when the amount of potassium is increased in the nutrient solutions the magnesium uptake by potato, tobacco, beet, barley, and certain fruit plants decreases, while when the amount of magnesium in the solutions is increased the potassium uptake is decreased.

When liming acid soils, an unfavorable ratio between calcium and magnesium may be created which could lead to a decrease of the magnesium uptake by plants; this is especially pronounced in calciophobic crops (potato, lupine, and seradella) and the application of magnesium fertilizers to them eliminates the negative effect of lime (3).

In our investigations of the effects of potassium fertilizers (in a green manure crop rotation system) there was an antagonism between potassium and magnesium in a number of crops, whereby the crop yield decreased in certain cases.

Fertilizers containing potassium and magnesium are being studied in a green manure crop rotation system at the Poless Agricultural Experiment Station, Gomel' Oblast'. The soil is sandy loam sod-podzolic soil on cohesive sand, underlain from a depth of 0.6-0.8 m, by moranic clay loam. The soil is strongly acid, its pH (KCl) is 4.10, its hydrolytic acidity is 2.81 meq, the sum of adsorbed bases is 0.39 meq/100 g of soil, and its degree of cation saturation is 12.2%. The exchange acidity is determined primarily by aluminum whose content is 5.3 meq/100 g of soil according to Sokolov; the P_2O_5 content is 4.0 mg/100 g of soil, according to Kirsanov. Exchangeable magnesium (in a 1 N extract of ammonium acetate) amounts to 9.1 mg, potassium to 60 mg, and calcium to 50 mg in 1 kg of soil. The total nitrogen content in the plowed layer (0-20 cm) is 0.03%; the P_2O_5 content is 0.10%; the K_2O content, 0.04%; the MgO content, 0.04%; the CaO content, 0.06%; the Fe_2O_3 content, 0.45%; the Al_2O_3 content, 1.05%; and the humus content according to Tyurin, 1.04%.

The amounts of potassium and magnesium fertilizers were studied in conjunction with nitrogen-phosphorous fertilizers under field crop rotation against three backgrounds: 1) lime (tuff lime) — 2.0 metric tons/ha $CaCO_2$; 2) well-decomposed lowland peat — 40 metric tons/ha; and 3) manure — 20 metric tons/ha. The manure contained 2.21% nitrogen, 0.34% P_2O_5, 1.23% CaO, 2.39% K_2O, and 0.43% Mg; the peat contained 4.08% nitrogen, 0.34% P_2O_5, 4.34% CaO_3, 0.068% K_2O, and 0.34% MgO, its pH (KCl) was 5.6; and the tuff lime contained 49.6% CaO, and 0.8% MgO. Manure, peat, and lime were applied to corn. The amounts of potassium applied to corn were 40 and 100 kg/ha K_2O in the form of 40% potassium salt. Magnesium was applied at a rate of 20 kg MgO in the form of magnesium sulfate.

Table 1

Effect of potassium and magnesium fertilizers on corn yield in green manure crop rotation

Fertilizer added to corn (background)	$N_{60}P_{40}$, cntr/ha ± m	$N_{60}P_{40}K_{100}$ cntr/ha ± m	$N_{60}P_{40}K_{100}$ cntr/ha ± m	$N_{60}P_{40}K_{100}Mg_{20}$ cntr/ha ± m
	Corn, 1957			
Manure, 20 met. tons/ha	286,2±6	283,8±10	306,8±16	310,2±11
Peat 40 "	271,2±3	285,8±6	316,8±13	326,0±10
$CaCO_3$ 2 "	210,8±5	269,0±8	226,4±9	224,6±3
	Corn, 1958			
Manure, 20 "	236,0±9	250,0±13	220,0±4	312,0±7
Peat 40 "	158,0±11	176,0±4	140,0±7	204,0±12
$CaCO_3$ 2 "	146,0±8	144,0±5	100,0±8	146,0±15
	Corn, 1959			
Manure, 20 "	311,0±4	320,4±7	339,3±9	352,4±8
$CaCO_3$ 2	280,2±8	290,7±6	291,7±9	297,3±7
Residual effect of fertilizers appl. to corn	$N_{45}P_{30}$	$N_{45}P_{30}K_{30}$	$N_{45}P_{30}K_{60}$	$N_{45}P_{30}K_{60}$ Mg_{14}
	Winter rye for green forage, 1958			
Manure, 20 met. tons/ha	115,0±9	116,4±7	122,8±12	125,0±8
Peat 40 "	111,2±7	115,0±10	117,0±7	117,2±14
$CaCO_3$ 2	80,4±11	106,8±8	117,2±9	116,0±13
	European yellow forage lupine, 1958			
Manure 20 "	490±15	496±19	489±16	522±13
Peat 40 "	468±12	483±13	491±18	502±10
$CaCO_3$ 2	419±13	459±17	460±11	479±14

Residual effect of fertilizers added to corn in 1957	$N_{45}P_{30}$		$N_{45}P_{30}K_{30}$		$N_{45}P_{30}K_{60}$		$N_{45}P_{30}K_{60}$ Mg_{14}	
	Grain, cntr/ha ± m	Straw	Grain, cntr/ha ± m	Straw	Grain, cntr/ha ± m	Straw	Grain, cntr/ha ± m	Straw
	Winter rye for grain, 1959							
Manure 20 met. tons/ha	26,6±1,3	42,0	25,0±0,5	42,0	25,6±0,8	42,0	28,6±0,4	44,0
Peat 40 "	26,6±0,3	42,0	27,0±0,4	44,0	26,6±1,1	44,0	28,0±0,6	43,0
$CaCO_3$ 2 "	22,6±0,3	37,0	25,8±1,0	42,0	25,6±1,3	43,0	27,2±0,7	40,0

Residual effect of fertilizers added to corn in 1957	$N_{30}P_{30}$		$N_{30}P_{30}K_{30}$		$N_{30}P_{30}K_{60}$		$N_{30}P_{30}K_{60}$ Mg_{40}	
	Grain, cntr/ha ± m	Straw	Grain, cntr/ha ± m	Straw	Grain, cntr/ha ± m	Straw	Grain, cntr/ha ± m	Straw
	Buckwheat, 1960							
Manure 20 met. tons/ha	7,4±0,7	25,4	7,9±0,4	31,6	7,2±0,8	31,7	10,4±0,2	41,1
Peat 40 "	7,0±0,8	21,4	7,5±0,5	28,8	6,8±0,7	25,2	11,3±0,6	42,9
$CaCO_3$ 2 "	6,1±0,6	22,3	6,7±0,9	27,2	5,7±0,6	28,4	9,9±0,7	43,9

Note: Comma represents decimal point.

Note: 1. No fertilizers were added to European yellow forage lupine. 2. Winter rye (for green forage, European yellow forage lupine, winter rye for grain, and buckwheat were sown in that order after corn.

The effect of potassium and magnesium on corn yield varied from background to background and from year to year (Table 1).

Magnesium had the strongest effect of the yield of corn during the wet year of 1958. Precipitation from April to October amounted to 453 mm in 1958, 259.4 mm in 1957, and 160 mm in 1959. The increased amount of potassium (100 kg/ha K_2O) against a background of lime reduced the yield considerably; against a background of manure and peat a decrease in

Table 2

Effect of potassium fertilizers on potassium and magnesium accumulation in the yield of crops used in green manure crop rotation

Fertilizer	Corn				Winter rye for forage, 1958		European yellow forage lupine, '58		Winter rye, 1959			
	1957		1958						Grain		Straw	
	MgO	K_2O	MgO	K_2O	MgO	K_2O	MgO	K_2O	MgO	K_2O	MgO	K_2O
Against manure background, 20 metric tons/ha												
NP	0,23	3,32	0,11	1,55	0,18	2,79	0,27	1,78	0,159	0,75	0,019	1,15
$NP + K_1$	0,17	4,67	0,09	1,80	0,16	2,96	0,24	2,33	0,145	0,76	0,017	1,22
$NP + K_2$	0,15	4,56	0,04	1,64	0,12	3,03	0,24	2,64	0,109	0,83	0,016	1,33
$NP + K_2Mg$	0,31	4,47	0,15	1,63	0,13	3,00	0,27	2,40	0,166	0,72	0,018	1,28
Against peat background, 40 metric tons/ha												
NP	0,23	2,92	0,18	1,25	0,10	2,06	0,25	1,60	0,145	0,78	0,019	0,40
$NP + K_1$	0,23	4,16	0,11	1,49	0,09	2,61	0,27	2,33	0,130	0,82	0,017	0,47
$NP + K_2$	0,15	4,14	0,13	1,90	0,10	3,07	0,23	2,87	0,130	0,80	0,016	0,53
$NP + K_2Mg$	0,20	3,76	0,17	1,79	0,14	2,60	0,26	2,41	0,150	0,71	0,017	0,35
Against $CaCO_3$ background, 2 metric tons/ha												
NP	0,21	2,82	0,19	2,58	0,16	2,38	0,16	1,77	0,142	0,76	0,016	1,06
$NP + K_1$	0,12	3,91	0,12	3,57	0,13	2,72	0,27	2,06	0,142	0,67	0,016	1,06
$NP + K_2$	0,14	4,36	0,07	3,81	0,08	2,93	0,17	2,39	0,105	0,64	0,014	1,52
$NP + K_2Mg$	0,19	4,24	0,15	3,48	0,12	2,63	0,28	2,13	0,161	0,60	0,017	1,48

Note: 1. No fertilizers were added to European yellow forage lupine; 2. Twenty metric tons/ha of manure, 40 metric tons/ha of peat and 2 metric tons/ha of $CaCO_3$ were added to corn in crop rotation; 3. The amounts of mineral fertilizers used on corn were: $N_{60}P_{40}K_{1-40}$, on winter rye — $N_{45}P_{30}K_{1-30}$, and K_{2-60} in the form of ammonium nitrate, superphosphate, and potassium salt; the amount of magnesium added to corn was 20 kg/ha MgO and to winter rye, 14 kg/ha MgO in the form of magnesium sulfate.

Note: Comma represents decimal point.

yield occurred only in 1958; while the yield increased somewhat in 1957 and 1959. However, the latter occurred only when the increased amount of potassium was added together with 60 kg/ha of nitrogen and 40 kg/ha P_2O_5 of phosphorus; when small amounts of phosphorus (P_{20}) were used, the yield decreased. As a chemical analysis of the corn shows (Table 2), the magnesium content in the plant is closely related to the potassium content. When potassium fertilizers were used, more potassium accumulated in the plants, but less magnesium. The addition of magnesium fertilizer to the soil increases the percentage of magnesium in plants, but somewhat decreases the percentage of potassium. The potassium and magnesium content in plants was especially low in the wet year of 1958.

To study the influence of various amounts of magnesium on yield and the accumulation of nutrients in corn plants, pot experiments were conducted with soils taken from control plots of the field experiment. The experiments were made in 1959 under a net in Mitscherlick-type pots. Seven kg of air-dry soil was added to the pots. Ammonium nitrate, superphosphate, potassium chloride, and magnesium sulfate were used as fertilizers. The experiment was replicated 4 times. The corn was sown on May 25 and the green mass was harvested on August 22.

Table 3 gives certain results of the pot experiment and of the chemical analysis of corn.

As we can see from Table 3, corn reacted well to the magnesium fertilizer, whereby the effect of various amounts of magnesium varied. With increased amounts of magnesium its content in the plants increased and that of potassium decreased. When 0.5 g of potassium and 0.03 g, 0.12 g, and 0.24 g of magnesium were used, the best effect was obtained with 0.12 g of magnesium, while the yield decreased when the double amount (0.24 g MgO) was used. Therefore when potassium and magnesium are added to the soil with fertilizers, the ratio between these elements should not be too narrow for corn. As the experimental data show, the best results are obtained with a K_2O:MgO ratio of 5:1 or 4:1, when the ratio between these elements is about 2:1, the effect of the magnesium fertilizer decreases noticeably. An excessive amount of magnesium decreased the concentration of calcium in the plants.

Table 3

Effect of magnesium on corn yield and nutrient accumulation in plants

Fertilizers	Yield		In % of absolutely dry matter				
	g per pot	%	MgO	K_2O	CaO	P_2O_5	N
NP	303 0	—	0,36	0,82	0,80	0,86	1,76
NPK	389,3	100	0,31	1,58	1,57	1,23	2,44
NPK + Mg_1	428,0	110	0,45	1,57	1,03	1,36	2,47
NPK + Mg_2	494,6	127	0,47	1,34	0,99	1,40	2,29
NPK + Mg_3	391,6	100,6	0,56	1,17	0,87	1,13	2,68

Note: To each pot was added: 0.5 g each of N, P_2O_5, and K_2O, and MgO (Mg_1—0.03; Mg_2—0.12; Mg_3—0.24).

Note: Comma represents decimal point.

In 1960, three amounts of magnesium in various combinations with four amounts of potassium in the form of sylvinite from the Soligorskiy Potassium Combine of the Belorussian SSR, and two amounts of chemically pure potassium chloride were studied in pot experiments with corn. The K_2O content in the sylvinite used in the experiment was 16.7%, and the MgO content, 0.54%.

The results obtained (Table 4) show that narrow ratios between potassium and magnesium (2:1 or 3:1) are less favorable than wider ratios. However, we can see from Table 4 that 0.08 g (MgO) of magnesium per pot had a better effect than the minimum (0.04 g) or the maximum (0.4 g) amounts in combination with almost all the tested amounts of potassium (from 0.1-1.0 g K_2O), except for the smallest (0.1 g in sylvinite), which gave a very weak effect anyway. Therefore not only the ratio between potassium and magnesium , but apparently also the amounts of magnesium and potassium fertilizers are of importance for increasing crop yield.

The effect of sodium nitrate on the yield of corn in field experiments on sandy soil was sometimes very weak as compared with that of ammonium nitrate or ammonium sulfate. This was confirmed in a pot experiment made in 1959 with the same soil as that used in the study of various amounts of magnesium. Plants on soil fertilized with sodium nitrate showed clear signs of magnesium starvation — there were white lines along the leaf veins, which merged in certain places into white spots. When magnesium was added to the soil fertilized with sodium nitrate, there were no white lines and spots on the corn leaves and the yield increased considerably. The effect of sodium nitrate increased by 130% as a result of magnesium (Table 5).

The magnesium content in plants on soil fertilized with sodium nitrate was less than in plants on soil with ammonium nitrate; when a fertilizer containing magnesium was added, the percentage of magnesium in the plants increased. An antagonism between the sodium in sodium nitrate and magnesium was noted by

Table 4

Effect of various amounts of magnesium in various ratios with various amounts of potassium on corn yield. 1960 experiment. The corn was sown on May 24, harvested on August 8, 1960

Potassium fertilizers and their amounts		Without magnesium	Amounts of MgO		
			0,04	0,08	0,40
N 1,0 P 1,0 (background)		326	—	—	—
bkgr.+ sylvinite	K 0,10	333	330	330	331
"	K 0,25	332	333	392	337
"	K 0,50	348	407	416	373
"	K 1,00	365	399	438	399
bkgr + KCl	K 0,50	359	362	398	382
bkgr + KCl	K 1,00	374	379	421	357

Note: Comma represents decimal point.

Table 5

Effect of magnesium and sodium nitrate on the corn yield and its chemical composition

Fertilizers	Yield		In % of absolutely dry matter				
	Yield	%	MgO	K_2O	CaO	P_2O_5	N
PK	17,6	—	—	—	—	—	—
PK + $NaNO_3$	81,3	100	0,177	2,95	0,514	0,35	1,86
PK + NH_4NO_3	159,6	196,3	0,211	1,93	0,643	0,31	2,23
PK + $NaNO_3$ + Mg	187,0	230,0	0,293	1,86	0,366	0,25	2,35
PK + NH_4NO_3 + Mg	219,0	269,0	0,484	1,58	0,431	0,24	2,46

Note: 0.5 g each of N, P_2O_5, K_2O and 0.08 g of MgO were added to each pot.

Note: Comma represents decimal point.

Mazayeva (10) for rustic tobacco.

After corn, winter rye for green manure was used in the crop rotation, the yield of which was assessed in the phase before ear formation (Table 1). Both amounts of potassium (30 and 60 kg/ha K_2O) applied to the winter rye had a positive effect on its yield. A small amount of magnesium (MgO_{14} kg/ha) gave no noticeable increase in yield.

European yellow lupine was sown after the winter rye to which no fertilizers were added, while their residual effect was studied. From the first stages of life to the stooling stage of the lupine the residual effect of the increased amount of potassium was negative, while as the lupine grew the difference between the residual effects of individual fertilizers leveled off considerably. Apparently, when penetrating deep in the soil the root system of the lupine provides the plant with nutrients not only from the plowed layer, but also from the underlying layer. A chemical analysis of the lupine in the flowering stage showed that the magnesium content decreased considerably from the residual effect of increased amounts of potassium fertilizers against the background of the residual effect of lime and peat, while this was not observed against the background of manure.

The fourth crop in the green manure crop rotation system was winter rye for grain. Potassium at a rate of 30 and 60 kg/ha K_2O was applied to the winter rye. The difference in the effect of the larger and smaller amounts was insignificant, while against a background of manure and peat the potassium fertilizer did not effect an increase in yield. The addition of magnesium increased the yield of winter rye considerably against all three backgrounds. The amount of magnesium used was small (14 kg/ha MgO) but it increased the grain yield and effected a noticeable increase of the magnesium content in it. When using mineral fertilizer systematically in crop rotation it is apparently necessary to add magnesium, since its deficiency in the soil shows down the further increase in yield.

After the winter wheat the fifth crop in the crop rotation system was buckwheat. The same amounts of potassium and phosphorus were applied to the buckwheat as to winter rye; somewhat less nitrogen was added — N_{30}, while the amount of magnesium was increased up to 40 kg/ha MgO. As we know, buckwheat removes a considerable amount of potassium from the soil, more than winter rye and certain other crops do. However, potassium fertilizers applied to buckwheat often produce only a small effect and sometimes act negatively.

As data in Table 1 show, the amount of potassium (K_{30}), corresponding to 0.5 cntr/ha of potassium chloride, increased the grain yield only by 0.5 cntr/ha, while the addition of 1.0 cntr/ha of potassium chloride gave a negative effect. A completely different picture was obtained when magnesium was used — the yield increased considerably when magnesium was added together with 1 cntr of potassium chloride. The increase in yield from magnesium varied from 3.2-4.5 cntr/ha. It must be noted that meteorological conditions in 1960 were very unfavorable for the growth and development of buckwheat. There was a drought during the flowering and filling of grain stages. There was almost no precipitation during the second and third decades of June and the first and second decade of July, while the air temperature rose to 30-33°C. But in spite of the drought, the magnesium fertilizer increased the yield considerably.

In another experiment the effect of ground dolomite, containing 15.7% MgO and 26.4% CaO, was studied in addition to that of magnesium sulfate. One and one-half times more magnesium was added with the ground dolomite than with magnesium sulfate (see Table 6).

The results of the experiments indicate that magnesium sulfate and ground dolomite have a favorable effect on the yield of buckwheat. The results of a chemical analysis of the plants in the mass flowering stage show that ground dolomite, as magnesium sulfate, promotes the accumulation of magnesium in the plants, but lowers the potassium uptake somewhat; potassium fertilizer (without magnesium) increases the potassium content, but decreases the amount of magnesium.

Table 6

Effect of magnesium fertilizers on the buckwheat yield and its chemical composition. 1960 experiment. Buckwheat was sown on May 30, harvested on July 27, 1960

Fertilizers	Grain, cntr/ha ± m	Straw, cntr/ha	In % of absolutely dry matter in the flowering phase mass				
			K_2O	MgO	CaO	P_2O_5	N
$N_{30}P_{40}$	9,3±0,3	18,5	2,78	0,41	1.74	0,54	1,80
$N_{30}P_{40}K_{60}$	8,4±0,8	26,3	3,49	0,32	2,03	0,53	1,70
$N_{30}P_{40}K_{60}$ + Dm 54 (by Mg)	10,4±0,5	32,4	3,02	0,54	1,76	0,57	1,80
$N_{30}P_{40}K_{60}$ + + $MgSO_4$ (Mg_{36})	9,8±0,7	35,6	3,09	0,66	1,87	0,61	1,70

Note: Dm — ground dolomitic, N — ammonium nitrate, P — superphosphate, and K — potassium chloride.

Note: Comma represents decimal point.

In the experiment of 1959 a comparison was made between the effect of ground dolomite and magnesium sulfate on potato yield (Table 7).

Data in Table 7 show that the magnesium in the ground dolomite has a somewhat better effect than magnesium sulfate. Under its effect potassium chloride effected a much greater increase in potato yield.

Conclusions

1. The uptake of magnesium and potassium from the nutrient medium by plant roots depends on a number of conditions, in particular on their quantitative relationship. An ample addition of potassium salts to the soil causes a decrease in the uptake of magnesium by plants and vice versa.

2. The deficiency of magnesium in sod-podzolic sandy loam soil manifests itself when increased amounts of potassium fertilizer are used. When 100 kg/ha K_2O are applied to corn the percentage of magnesium in the plants decreases noticeably, while that of potassium increases. Corn reacts differently to magnesium fertilization from year to year; the positive effect of magnesium is stronger in wet years.

3. Winter rye is rather sensitive to a magnesium deficiency. Sixty kilograms per hectar of potassium lowered its accumulation in the

Table 7

Effect of various amounts of potassium chloride and magnesium fertilizers on potato yield

Amounts of potassium and magnesium	Manure, 30 metric tons/ha		
	Tuber yield, cntr/ha ± m	Yield increment, cntr/ha	% of starch
Without mineral fertilizers	141,6±3,6	—	16,8
K_{40} (KCl)	150,0±3,8	8,4	15,3
K_{80} (KCl)	153,0±6,3	11,4	15,5
K_{120} (KCl)	158,9±3,8	17,3	15,7
$K_{40}Dm_{24}$ (by Mg)	158,6±4,8	17,0	15,4
$K_{80}Dm_{36}$ (by Mg)	170,5±4,1	28,9	15,3
$K_{80}MgSO_4$ (Mg_{36})	167,0±3,3	25,4	15,3

Note: Dm — ground dolomitic. The ground dolomitic contained 20.7% MgO and 28.3% CaO.

Note: Comma represents decimal point.

plants, even though the yield did not decrease. The addition of magnesium fertilizer increased the yield.

4. Buckwheat reacted most strongly to magnesium fertilizers, especially when potassium was added to the soil. Magnesium fertilizers sharply increase the positive effect of potassium.

5. European yellow lupine suffers from a magnesium deficiency on coarse-textured sandy loam and sandy soils primarily in its young stages, until it develops a strong root system. Later the necessary amount of magnesium is provided for by the plowed and underlying layers.

6. A good source of magnesium fertilizer is ground dolomite, which is superior in its effect to magnesium sulfate.

Ground dolomite added to potatoes enchances the effect of potassium chloride.

Received April 4, 1960

BIBLIOGRAPHY

1. ANGREYENKO, S. S. and F. M. KUPERMAN. 1959. Physiology of corn. Izd-vo MGU.
2. ANDREWS, W. C. 1959. Use of organic and mineral fertilizers. Moscow, Izd-vo in. lit. (Translation from English).
3. KEDROV-ZIKHMAN, O. K. 1948. Effect of liming on the magnitude and quality of the yield of agricultural plants, depending on the magnesium content in the lime fertilizer and the use of boron. Izv. Akad. Nauk BSSR. No. 1.
4. KOLINGS, D. KH. 1958. Plant nutrients other than N, P, and K. The use of mineral fertilizers abroad. Sel'khozgiz.
5. MAGNITSKIY, K. P. 1952. Magnesium fertilizers. Sel'khozgiz.
6. MAGNITSKIY, K. P. 1951. The effect of magnesium fertilizers on coarse-textured sod-podzolic soils. Sov. agronomiya, No. 2.
7. MAGNITSKIY, K. P. 1957. Effectiveness of magnesium fertilizers on sandy and sandy loam soils. Udobreniye i urezhay. No. 12.
8. MAGNITSKIY, K. P. 1949. Effect of magnesium fertilizers on potatoes. Sad i ogorod. No. 4.
9. MAGNITSKIY, K. P. 1961. Symptoms of deficiency and of harmful excess of individual elements in potatoes. Sad i ogorod. No. 3.
10. MAZAYEVA, M. M. 1944. Conditions for the positive effect of magnesium fertilizers. Izv. Akad. Nauk SSSR, ser biol.
11. MAZAYEVA, M. M. 1950. Sensitivity to a magnesium deficiency and the photoperiodic reaction of plants. Dokl. Akad. Nauk SSSR. 73(1).
12. SHEMPEL', V. I. 1939. Importance of calcium and magnesium in the liming of virgin lands. Akad. Nauk BSSR, MINSK.
13. JACOB, A. 1955. Magnesia, der fünfte Pflanzenhauptnährstoff. Stuttgart, Enke.
14. SCHARRER, K. and K. MENGEL. 1958. Über den Kalium-Magnesium-Antagonisms bei Mais und Sonnenblumen. Zeitschr. f. Pflanzenernähr., Düng. Bodenk. 83(2).

INFLUENCE OF PINE AND BIRCH FORESTS ON THE SOILS OF THE SOUTHERN URALS

YU. D. ABATUROV, Ul'men Reservation, Urals Branch of the Academy of Sciences of the USSR

The problem of the interrelationship between woody vegetation and soils has long attracted the attention of investigators since it is of great practical and theoretical importance. It permits the proper conduct of one or the other measures in forestry and promotes the further development of silviculture. These interrelationships are complicated and many-sided and manifest themselves differently under various geographical and ecological conditions (2, 4). They are best known under the level areas of the European USSR. They have been studied little in the Urals and in Siberia, where climatic and soil conditions have specific characteristics.

The present article is devoted to the study of one of the aspects of the foregoing relationship, namely the influence of woody vegetation on soils. We examined certain characteristics of the effect of pine and birch forests on soils. The investigations were conducted in 1957 and 1958 at the V. I. Lenin Il'men' State Reservation.[1]

The Reservation is located in the northern part of the eastern foothills of the Southern Urals. The climate of the Reservation is moderately continental. According to the data of the "Miassovo" meteorological station, the mean annual temperature is 1.8°C, the mean annual precipitation is 454 mm; and the frost-free period lasts 119 days (1). The work was conducted in two permanent and six temporary experimental areas.

The permanent experimental areas (No. 24, a mixed-herbage fern pine stand, and No. 25, a mixed-herbage fern birch stand) are located in the lower part of an eastern slope. The slope does not exceed 5°. Both areas immediately adjoin each other. A clearing the size of a compartment serves as boundary between them. The temporary experimental areas were selected in pairs (pine stand and birch stand) in the same forest vegetation conditions, close to each other, whenever possible (Table 1).

All of the birch stands are naturally produced. We can state more or less definitely that the replacement of pine by birch occurred in the first generation: in almost all experimental areas we found the overgrown remains of semi-decomposed charred pine stumps in the birch stands.

In all cases the soils are sod-podzolic with differing degrees of podzolization. To compare the morphological structure of the soils we give the description of soils in experimental areas No. 24 and No. 25.

Experimental area 24. Mixed-herbage fern stand with a thin undergrowth of broom, mountain ash, and dog rose. The grass cover consists of mixed grasses, herbage, and ferns of an uneven composition and density. There is little sod. Green mosses, predominantly Pleurozium shreberi, are found in small patches.

A_0 0-4 cm. Non-decomposed pine litter at the surface. Below — compact, slightly decomposed litter. Contains a lot of fungus mycelium in places. Charcoal is found. The litter is somewhat loosened by grass.

A_1 4-12 cm. Dark-gray. Fine-grained structure, rather stable. Friable. Medium clay loam. Contains many roots, predominantly from grasses. The transition to the underlying horizon is clear in color, density, and structure.

A_2 12-35 cm. Whitish-light-gray. Leafy-porous structure, weak. Medium clay loam with little gravel. The transition is clear in color, density, and structure.

B 35-50 cm. Reddish-cinnamon-brown, nutty-lumpy, compact, fine clay loam, containing somewhat more gravel than the preceeding horizon. Occasionally contains small (5-10 cm in diameter), rolled back fragments.

BC 50-81 cm. Products of rock weathering. Cinnamon-brownish clayey coatings are found on the faces of particles. Strongly skeletal. Poorly-defined structure.

CD 81-110 cm. Weathered rock (gneiss-granite).

Experimental area 25. Mixed-herb fern

---

[1] The work was conducted under the supervision of Professor S. V. Zonn.

Table 1

Brief evaluation of the tree stands

Experimental area No.	Forest type	Average			Density	Site quality	Composition
		Age	Diameter	Height			
25	Mixed-herb fern birch stand	50	20	24	0,8	II	10 B + P
3	"	45	18	20	1,0	III	10 B
4	"	40	18	21	0,7	III	10 B
5	"	50	20	21	0,9	III	10 B
24	Mixed-herb fern pine stand	120	38	30	0,9	I	10 P
1	Mixed-herb grass pine stand	120	32	26	0,9	II	10 P
2	Grass mixed-herb pine stand	120	28	23	0,8	II	10 P
6	Mixed-herb fern pine stand	43	20	19	0,8	II	7 P3B

Note: Comma represents decimal point.

birch stand with a thin undergrowth of willow and mountain ash. The grass cover consists of mixed herbage and ferns, including legumes and broadleaf grasses; there is little sod. Mosses are rare (*Mnyum*, etc.).

A_0 0-2 cm. Loose birch litter and grass remains, absent in places. A large amount of caprolite at the boundary between the litter and the mineral horizons of the soil.

A_1 2-14 cm. Dark-gray, becoming lighter with depth; containing darker tongues extending to a depth of 20 cm. Stable, lumpy-granular structure. Friable. Medium clay loam. There is a lot of caprolite in the upper part of this horizon. The transition to the A_2 horizon is clear.

A_2 14-28 cm. Whitish-gray, Weak leafy-porous structure, slightly compacted. Medium clay loam. The transition to the B horizon is clear.

B 28-45 cm. Reddish-cinnamon-brown, nutty-lumpy, compact, fine clay loam, gravelly. The transition to the BC horizonis gradual.

BC 45-75 cm. Products of gneiss-granite weathering. Cinnamon-brown clayey coatings along the faces of structural units.

CD 75-100 cm. Products of gneiss granite weathering.

As we can see from the foregoing descriptions there are noticeable differences in the morphological structure of the soils. They manifest themselves in the thickness, color, structure, and compactness of the A_1 and A_2 horizons. These differences are characteristic of all the soils studied. The thickness of the A_1 horizon in the pine stands varies from 8-11 cm and in the birch stands, from 10-15 cm. The A_2 horizon is thicker in the pine stands than in the birch stands. Its thickness under the pines varies from 16-23 cm, and under the birches, from 13-18 cm. Statistical analysis showed that the difference in the thickness of the A_1 and A_2 horizons of the soils in the pine and birch stands is quite reliable.

The A_1 and A_2 horizons in the pine stand are somewhat lighter in color, have a less stable structure, and, judging by the bulk density (Table 2) are more compact than the same horizons in the birch stand.

The difference in the degree of podzolization is also confirmed by the results of the total

Table 2

Bulk density of the soil, g/cm³

Pine stand, experimental area 24		Birch stand, experimental area 25	
Horizon and depth, cm	Bulk density	Horizon and depth, cm	Bulk density
A_1 4—12	0,95±0,05	A_1 2—14	0,91±0,03
A_2 12—35	1,42±0,03	A_2 14—28	1,31±0,02
B 35—50	1,53±0,03	B 28—45	1,49±0,04
BC 50—81	1,51±0,01	BC 45—75	1,50±0,01

Note: Comma represents decimal point.

chemical analysis of the soils (Table 3). The A_2 horizon of the soil under the pine stand stands out in the distribution of oxides. It is characterized by a high SiO_2 content and a low content of R_2O_3 (especially Fe_2O_3) and of calcium and magnesium oxides. The A_2 horizon of the soil under the birch stand is also pronounced, but less sharply. This indicates that eluviation proceeds more actively under the pine stand than under the birch stand. In the latter, biological accumulation predominates over leaching, judging by the distribution of iron, calcium, and magnesium oxides.

Differences between the soils under the pines and birches also manifest themselves in the amount of humus, exchangeable bases, and soil acidity (Table 4). The upper soil horizons and, especially, the litter are less acid in the birch stand than in the pine stand. The difference in acidity levels off with depth and the acidity of the BC and CD horizons is the same. This is attributable to differences in the acidity of the litter and its distribution.

The upper soil horizons in the birch stands have a higher humus and exchangeable base content. There is also a higher amount of mobile iron compounds in the upper soil horizons under the birch stands.

All this indicates that present soil formation proceeds differently in soils under pine and birch stands.

What are the reasons for these differences? As we have already noted, all experimental areas are located in similar forest vegetation conditions and on the same soil-forming parent material. The only difference between the experimental areas consists in the composition of vegetation. Consequently, the difference in the nature of soil formation must be attributed to the difference in the effect of woody as well as of the grassy vegetation accompanying it.

The influence of woody vegetation on soils is determined first of all by the intensity and nature of the biological cycle (2, 4, 5).

We can see that the main members of the biological cycle are: 1) the requirement of nitrogen and ash elements from the soil by plants, 2) their return to the soil, and 3) the rate and nature of the decomposition of plant residues.

We determined the amounts of substances utilized and returned by the plant tops. This has allowed us to judge of the comparative intensity of the biological cycle in various types of forests.

The requirement of nitrogen and ash elements by plants from the soil consists of the amount of substances used for the annual growth increment of wood, needles and leaves, shoots, fruits, seeds, and the grass and moss cover.

The amount of vegetative mass forming annually was determined in the following manner. The increment of needles and leaves was conditionally taken as equal to their annual fall. To determine the fall in the permanent experimental areas, five collectors, each 1 m² in area, were set up. The accuracy of this method of determining the amount of needles and leaves shed was 5%-10%. The annual increment in wood and branches was determined from growth tables (5).

The amount of grassy vegetation was determined by cutting it 5 times from 1 m² areas.

The amount of vegetative mass forming annually is shown in Table 5.

More vegetative mass forms in the birch stand than in the pine stand; the difference is especially great in the amount of wood and grass-moss vegetation. There was more of the vegetative mass (fruits, shoots, and bark scale) in the pine stand than in the birch stand.

Differences in the amount and composition of

Table 3

Total chemical analysis of soils, % of ignited sample

Experimtl. area No.	Horizon and depth, cm	Ignition losses	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	TiO_2	CaO	MgO	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
24	A_1 4—12	12,78	67,95	21,91	2,38	18,09	1,44	4,10	1,84	6,4	75,8	11,8
	A_2 12—35	5,14	70,12	18,69	2,07	15,97	0,65	3,23	1,25	7,5	90,0	12,0
	B 35—50	6,18	58,71	30,15	3,45	26,00	0,69	4,86	2,16	3,8	43,6	11,8
	BC 50—81	7,96	63,70	23,96	2,58	20,70	0,68	5,05	3,87	5,2	65,5	12,5
	CD 81—110	2,22	63,83	24,41	2,84	20,78	0.50	4,30	0,92	5,2	59,7	11,4
25	A_1 2—14	14,43	67,26	21,46	3,24	17,15	1,07	4,98	3,99	6,5	55,1	8,3
	A_2 14—28	6,82	68,52	19,22	2,84	15,72	0,66	4,19	2,30	7,4	64,2	8,7
	B 28—45	7,84	61,51	28,33	3,75	23,85	0,73	4,99	2,54	4,4	43,6	9,5
	BC 45—75	4,61	61,34	23,66	3,30	20,15	0,21	4,80	2,60	5,2	49,3	9,5
	CD 75—100	4,88	66,68	24,68	2,90	21,51	0,27	4,56	1,64	5,2	61,4	11,7

Note: Comma represents decimal point.

Table 4

Brief physicochemical description of the soils

Pine stand								Birch stand							
Experimntl. area No.	Horizon and depth, cm	pH of water suspension	Humus (accord. to Tyurin) %	Exchangeable bases, meq/100 g of soil			Mobile Fe_2O_3 (accord. to Kirsanov), mg/100 g of soil	Experimntl. area No.	Horizon and depth, cm	pH of water suspension	Humus (accord. to Tyurin) %	Exchangeable bases, meq/100 g of soil			Mobile Fe_2O_3 (accord. to Kirsanov), mg/100 g of soil
				Ca^{++}	Mg^{++}	Total						Ca^{++}	Mg^{++}	Total	
24	A_0 0—4	5,1	—	51,0	14,5	65,5	17,5	25	A_0 0—2	6.0	—	55,2	19,5	74,7	87,7
	A_1 4—12	5,2	2,43	8,8	2,4	11,2	18,0		A_1 2—14	5,8	4,6	17,0	3,4	20,4	42,2
	A_2 12—35	5,3	0,54	8,0	1,9	9,9	28,0		A_2 14—28	6,0	1,1	9,8	2,6	12,4	16,2
	B 35—50	5,6	0,47	19,4	16,4	35,8	92,0		B 28—45	5,8	0,9	10,3	3.2	13,5	31,1
	BC 50—81	5,4	0,31	25,9	21,8	47,7	36,0		BC 45—75	5,6	0,8	23,6	14,8	38,4	14,0
	CD 81—100	5,5	0,14	21,4	9,9	31,3	—		CD 75—100	5,6	0,4	7,6	4,7	12,3	5,8
1	A_0 0—5	5,0	—	—	—	—	16,0	3	A_0 0—1	6,1	—	—	—	—	—
	A_1 5—14	5,6	3,9	13,8	3,9	17,7	18,0		A_1 1—11	5,7	7,5	22,5	7,3	29,8	—
	A_2 14—27	5,8	0,9	8,5	3,1	11,6	19,0		A_2 11—24	5,4	2,2	14,4	5,2	19,6	—
	B 27—46	5,9	0,4	15,0	6,8	21,8	27,0		B 24—32	5,6	1,8	18,4	6,9	25,2	—
	BC 46—64	5,8	0,2	10,1	4,6	14,6	27,0		BC 32—49	5,3	0,6	16,3	6,4	22,7	—
	CD 64—80	5,6	0,2	6,4	2,6	9,0	21,0		CD 49—83	5,4	0,2	15,2	6,6	21,8	—
2	A_0 0—3	5,5	—	—	—	—	—	4	A_0 0—1	5,8	—	45,1	18,6	63,7	—
	A_1 3—14	5,4	4,3	15,1	5,2	20,3	—		A_1 1—15	6,0	5,8	23,3	8,5	31,8	—
	A_2 14—30	5,3	1,1	9,0	3,8	12,8	—		A_2 15—30	5,9	0,5	8,1	2,8	10,9	—
	BC 30—63	5,4	0,5	12,7	5,1	17,8	—		B_1 30—63	5,7	0,2	13,3	5,1	18,4	—
	CD 63—102	5,5	0,3	11,4	4,5	15,9	—		CD 63—105	5,6	0,2	9,0	2,9	11,9	—
6	A_0 0—3	5,6	—	—	—	—	11,0	5	A_0 0—2	6,0	—	—	—	—	32,0
	A_1 3—11	5,8	2,9	15,7	11,8	27,5	57,0		A_1 2—17	6,2	5,3	27,2	12,1	39,3	23,0
	A_2 11—34	5,3	0,7	8,3	4,3	12,6	43,0		A_2 17—35	5,8	1,4	14,3	7,2	21,5	23,0
	BC 34—49	5,6	0,6	2.4	1,1	3,5	41,0		B 35—67	5,6	0,8	7,9	3,6	11,5	55,0
	CD 49—70	5,3	0,9	2,1	0,8	2,9	—		CD 67—100	5,5	0,3	8,7	2,6	11,3	16,0

Note: Comma represents decimal point.

Table 5

Amount and composition of the annually forming vegetative mass, kg/ha

Experimental area No.	Forest type	Woody vegetation				Grass-moss vegetation	Total
		Wood	Needles-leaves	Other	Total		
24	Mixed-herb fern pine stand	3000	1210	756	4966	1400	6366
25	Mixed-herb fern birch stand	4500	1640	403	6543	2100	8643

the vegetative mass forming annually also determine the difference in the requirement of nitrogen and ash substances from the soil (Table 6). Nitrogen and ash substances are used primarily for the formation of grass vegetation both in the pine and in the birch stand. It uses up almost half of all the substances, which is attributable, first of all, to its high ash content which reaches 10% in grasses.

Needles and leaves occupy the second place in the amount of substances they use, but there are considerable differences between the two. The ash and nitrogen content is more than twice as high in birch leaves than in pine needles.

The amount of nitrogen and ash substances used to produce the current increment of wood is of little importance in the total requirement of the foregoing elements. This is attributable to the low ash content of wood, which does not exceed 1%-2%. The consumption of these elements in the formation of fruits, shoots, and bark scale (other parts), which require little nitrogen and ash substances, is also of little importance in the total amount of substances used.

As far as the requirement of individual elements is concerned, the greatest difference between the pine and birch stands is in the uptake of calcium, magnesium, and iron. The birch stand consumes almost three times more of these substances than the pine stand, and more than twice as much as the other substances, except for SiO_2, which is used almost in the same amounts.

Table 6

Amount of nitrogen and ash substances used, kg/ha

Exper. area No.	Item	N	SiO_2	R_2O_3	Fe_2O_3	P_2O_5	K_2O	CaO	MgO	SO_3
25	Leaves	48,2	7,4	11,7	3,6	5,1	21,2	32,9	12.5	5,7
	Other parts	2,7	0,8	1,1	0,2	0,7	1,7	1,7	0,8	3,1
	Wood	9,1	0,5	7,7	0,5	3,2	5,8	11,0	3,6	8,2
	Grass cover	40,0	53,4	11,3	2,5	13.0	59,5	45,0	18,9	19,8
	Total	100,0	62,1	31,8	6,8	22,0	88,2	90,6	35,8	36,8
24	Needles	18,4	0,8	4,6	0,8	2,7	6,3	9,9	3,4	4,9
	Other parts	3,0	3,8	5,4	0,4	1,1	2,7	2,8	0,9	4,7
	Wood	5,5	0,3	6,7	0,7	1,8	3,4	5,8	1,5	2,0
	Grass cover	21,6	44,0	2,5	0,7	5,7	34,4	18,9	8,4	13,3
	Total	48,5	48,9	19,2	2,6	11,3	46,8	37,4	14,2	24,9

Note: Comma represents decimal point.

There is also a difference in the order of distribution of elements taken up from the soil. The birch stand consumes a maximum amount of nitrogen, calcium, and potassium. Silica is in fourth place. Phosphorus and iron are in last place. The order is different in the pine stand: silica occupies the first place, then nitrogen, potassium, and calcium. The order of distribution of the other elements is the same as in the birch stand.

The basic mass of the substances used is returned to the soil with the litter, and only an insignificant amount is retained in the current wood increment.

Substances which enter the soil with the litter are included in the cycles only as the litter decomposes. Therefore, the rate at which litter decomposes is of great importance in the biological cycle. The rate may be determined by the amount of litter. The amount of litter in the birch stand is 5-6 metric tons/ha of air-dry mass, and in the pine stand it reaches 20-25 metric tons/ha. A comparison between the amount of litter and the amount of annual fall shows that the amount of litter in the pine stand exceeds the amount of fall 6-7 times, while in the birch stand it does not exceed by more than 1.5 times. The litters differ also in their ash composition (Table 7).

The content of iron and potassium in the birch litter is more than two times higher than in the pine litter; and that of total nitrogen is 1.5 times higher. The phosphorous and calcium content is somewhat higher in the birch litter. There is more silica and magnesium in the pine litter.

When comparing the ash content of the vegetation and of the litters we can see clearly that it is higher in the latter, especially in the birch litter. The birch litter accumulates iron while the pine litter accumulates silica. Calcium and magnesium are almost completely leached as both litters decompose.

Judging by the morphological structure of the litters, the process of their decomposition differs in the birch and the pine stands. This is also confirmed by the composition of humic substances, which depends not only on the composition of the plant residues, but also to a great extent on the nature of their decomposition (Table 8). The humic acid content is higher in the birch litter than in the pine litter, a fact which is confirmed by the ratio between the C of humic acids and the C of fulvic acids.

It must be noted that in the birch litter there is somewhat more carbon of humic compounds bound with calcium and magnesium and less carbon of substances extractable with benzene alcohol. Acids forming during the decomposition of the litter are neutralized only by bases contained in the litter itself. But, as already mentioned earlier, the vegetation in the pine stand contains almost 4 times less calcium and magnesium than that in the birch stand. As a result, considerably more acid products of decomposition, unsaturated with bases, form in the main litter. The difference in the acidity of the litters is also enhanced by the fact that the plant residues themselves which

Table 7

Content of nitrogen and ash elements in the litter, % of absolutely dry matter

Experimental area No.	N	SiO_2	R_2O_3	Fe_2O_3	P_2O_5	K_2O	CaO	MgO	SO_3	Total	Admixture
24	0,99	4,10	0,82	0,27	0,31	0,45	0,48	0,27	0,48	7,18	5,53
25	1,54	3,96	1,58	0,76	0,40	1,01	0,53	0,19	0,57	9,00	9,87

Note: Comma represents decimal point.

Table 8

Composition of humic substances in litters, carbon of various fractions in % of total carbon in the soil

Experimentl. area No.	Initial C, % of litter weight	C in the benzene alcohol extract	C of substances extracted with soil decalcification	C of humic acids			C of fulvic acids			C of residue	Total	C of humic acids / C of fulvic acids
				Fractions		Total	Fractions		Total			
				I	II		I	II				
24	30,42	10,23	1,18	1,05	3,02	4,07	4,18	0,89	5,07	76,00	96,55	0,80
25	23,61	9,50	1,89	1,42	4,75	6,17	4,44	1,05	5,49	72,60	95,66	1,12

Note: Comma represents decimal point.

form the litter vary in acidity: the pH of the water suspension of pine litter is 5.7 and that of the birch litter is 6.9.

The acid products of litter decomposition, which are not saturated with bases, determine the processes of podzolization when they penetrate into the lower-lying mineral soil horizons and interact with them.

Conclusions

1. When pine stands are being replaced by birch stands under conditions of the Il'men Reservation, the process of podzol formation is suppressed.

2. The qualitative composition of litter and the nature and conditions of the decomposition of the forest litter play a decisive part in the effect of various woody plants on soils.

Received December 26, 1960

BIBLIOGRAPHY

1. ZHARIKOV, S. S. 1959. Climate of the Il'men' Reservation area and adjoining areas of the Southern Urals. Tr. Il'menskogo gos. zapoved. im. V. I. Lenina. No. 7. Miass-Chelyabinsk.
2. ZONN, S. V. 1957. Forest soils of Bulgaria. Izd. Akad. Nauk SSSR.
3. KOLESNIKOV, B. P. 1958. Botanical-geographical and silvicultural regionalization of the Chelybinsk Oblast'. Manuscript. Botanicheskiy Institut Ural'skogo Filiala Akademii Nauk SSSR.
4. REMEZOV, N. P. 1956. Role of the biological cycle of ash elements in soil formation in a forest. Pochvovedeniye, No. 7.
5. ROZANOVA, I. M. 1960. Cycle of ash elements and change in the physico-chemical properties of leached chernozems under coniferous and broadleaf plantations. Tr. Lab. lesoved. Akad. Nauk SSSR. Vol. 1.
6. TYURIN, A. V. and others. 1956. Forest manual. Goslesbumizdat.

AGRONOMY [illegible]
305 [illegible]

ORIGIN OF SOILS WITH A WHITISH HORIZON IN THE PLAINS OF THE AMUR REGION

E. A. KORNBLYUM, and B. A. ZIMOVETS, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

A considerable part of the lands suitable for plowing in the territory occupied by the alluvial-lacustrine plains of the Amur region in the USSR and in China consists of meadow and forest soils with a whitish horizon. In outward appearance they resemble solods or sod-podzolic soils. The majority of investigators believed, along with Ivanov (15) and Glinka (9), that they were podzolic or sod-podzolic soils (1, 4, 13, 20, 30, 31, 32, etc.). Liverovskiy (21) assumed that soils with a whitish horizon in the Khanka plain originated as a result of solodization. Later (22) he assumed the same of the soils of the Zeya-Bureya plain. In a new soil classification scheme for the plains of the Far East (23), Liverovskiy and Rubtsova included meadow-gleyey soils, formed as a result of a "peculiar variable gleization process" (p. 67) among soils with a whitish horizon, along with solodized and podzolized soils. The results of the Amur Expedition of the Academy of Science of the USSR and the Academy of Sciences of the Chinese People's Republic, which supplement the data published earlier, permit us to propose a new theory on the genesis of the foregoing soils and to show that their formation differs noticeably from the processes of soil formation mentioned earlier, even though it has a number of common characteristics with them. In the system of mountain zonality, the region with soils with a whitish horizon lies below the zone of forest brown earths. The area of these soils embraces the Suyfun-Khanka, Amur-Ussuri, and the Zeya-Bureya plains, the northern and eastern borders of the Central Manchurian depressions, the foothills of the ranges surrounding these depressions, and smaller mountain basins. Soils with a whitish horizon are especially widespread in the southeast of the area — in the Khanka plain and on the terraces of the Ussuri River.[1] Here, in the soils of the meadow-steppe and brushwood coenoses, the shallow (15-20 cm) layer of soft, gray humus changes suddenly into the eluvial horizon (A_2)[2] which is 20-40 cm thick. The latter is of a yellowish-white color, compact, has fine pores, and crumbles into leafy-platy fragments. The color of the horizon gave rise to the Chinese name for these soils: "beydzhan (peichiang)-tu" — "soils as white as milk." There is a huge amount of rust and black concretions in the whitish horizon. A gray-brown humus-illuvial horizon begins from a depth of 40-60 cm; it has a finely nutty, sharp-edged structure with gel-like concretions on the faces, on which a silty-sandy powdering appears on drying. Illuviation phenomena extend to a depth down to 2-2.5 m.

The climatic conditions for the formation of such soils are characterized by a contrasting hydrothermal regime. Southeastern monsoons prevail in the Amur region in summer, bringing moisture from the ocean. The later part of the summer is characterized by a combination of maximum (for the year) precipitation with maximum temperatures with a very high relative humidity. Intense reduction processes take place in soils developed on fine-textured parent materials and having large amounts of dead organic matter. This leads to a temporary gleization of the upper mineral horizons. The dry spring and autumn are the periods when oxidation processes take place when a large amount of moisture in the soil moves by lateral drainage and downward along the profile (25). The considerable interseasonal fluctuations of the oxidation-reduction regime are also associated with weather changes.

There is a close relationship between the spatial changes in the morphological characteristics of the foregoing soils and changes in the nature of oxidation-reduction processes, their intensity and contrast. The great longitudinal and latitudinal extent of the area with "peichiang-tu" and the complexity of the structure of the surface are the causes for the great changes in bioclimatic conditions of soil formation. A whitish horizon is found in the soils of waterlogged sedge-reedgrass meadows, steppe-like mixed-grass meadows, mixed-herb-arundinaria steppe groups, cedar-broadleaf forests, oak-lespedeza forests, birch-larch and spruce-larch taigas, southern swamps, and many other plant associations. It is only natural that with such variety of plant associations the soils which develop under their influence are also varied, even though they are united into one group by a specific eluvial process. Changes in soil characteristics occur in three main directions: 1) from south to north, toward the northern part of the monsoon region; 2) from the southeast to the northwest, toward the continental regions of Siberia; and 3) toward the mountains.

---

[1] Most of the material published is devoted to the soils of these areas.

[2] For the eluvial horizon (beydzhan-tu) which forms, as is shown later, as a result of leaching and the variable-gleization process, we could have apparently used the designation A_{eg} to distinguish it from the A_2g of podzols.

The change in the morphology of the soils toward the north is associated with the stabilization of the reduction regime as a result of increased moisture and decreasing temperatures. The soils of the southern taiga and swamps are characterized by the weakening of eluviation, by a steady gleization of the A_2 horizon, located under a coarse humus-peat layer, and the replacement of concretions, characteristic for southern soils, by rusty spots and tongues.

In the more continental regions, in the Zeya-Bureya plain, soils with a whitish horizon are replaced in flat areas by soils similar to chernozem-like prairie soils, and develop only in better drained areas, such as slopes and the edges of terraces (22).

In the foothill, soils of grass associations are replaced by forest soils which also have a whitish horizon. The forest peichiang-tu are characterized by a poorly defined illuvial horizon. The amount of concretions in the thick brightly whitish eluvial horizon of soils on the upper parts of slopes decreases sharply as compared to soils at the foot of the slopes. The whitish horizon in the soils of mountain river terraces gradually becomes less pronounced with elevation (32). Peichiang-tu is replaced by brown forest soils on the fragmental eluvium and deluvium of mountain slopes.

The manifestation and intensity of eluviation depend on the distribution of the soils along the relief and their texture, a fact that was noticed by Yaroshenko (36) and confirmed by our investigations in various soil-climate zones. The whitish horizon does not form in soils in small undrained depressions, where reduction conditions are stable, but in fine-textured soils, where reduction processes are weak and temporary.

The foregoing leads to the conclusion that the variable nature of oxidation-reduction processes, under conditions permitting the removal of the products of soil formation beyond the profile, is apparently the main reason for the development of the eluvial process in peichiang-tu, as well as in podzolic soils and solods (34, 35).

A necessary condition for the formation of soils with a whitish horizon is the presence of a fine-textured material. In the huge areas occupied by peichiang-tu, the fine-textured material (light-brown clays and clay loams) has constant properties. In spite of the variations in texture from layer to layer, the content of clay (30%-60%), fine silt (10%-40%), and coarse silt (30%-40%) is always high. The finely-dispersed clay in brown clays consists of minerals of the hydromica and montmorillonite groups, iron oxide and hydroxide, and an insignificant amount of kaolinite, palygorskite, and quartz. The clay swells considerably in water and deep vertical cracks form in it on drying.[3]

The reaction of the clays is neutral. The adsorption capacity of their finely-dispersed fraction is 40-50 meq/100 g (10). The Ca^{++}:Mg^{++} ratio is usually close to 1 and does not exceed 1.5. No Na^+ was found by us in the adsorption complex at a depth of 2-3 m.[4] There is also a lack of readily-dissolved salts. The ground water is fresh to a depth of 100 m, with bicarbonate-calcium salts (12).

The development of the eluvial process leads to the formation of a "two-membered" soil profile. The clay content in the A_1 and A_2 horizons decreases by 50%-60% and more as compared to the parent material. The intense removal of mineral colloids from the humus horizon is partly compensated by the accumulation of organic colloids (29). Removal can be replaced by accumulation at a depth of 60-100 cm. The differences in the texture of the upper and lower parts of the profile of peichiang-tu correlate with the spatial changes in the oxidation-reduction regime, which points to the development of the "two-membered" profile in the course of soil formation. In its turn, such a "two-membered" profile stimulates gleization and the development of the eluvial process, as noted by Krauss (37).

Is the eluvial horizon a relict (21, 22, 31) or a contemporary formation? Earlier we mentioned the relation between the clearness of the eluvial horizon and present climatic conditions. One of the indications of the contemporary nature of the process of eluviation is the occurrence of peichiang-tu on surfaces of various ages: from early Quaternary regions to the first flood-plain terraces of rivers. The structure of the humus horizon also confirms the contemporary nature of the eluvial process. The humus content decreases sharply in the A_2 horizon as compared to the humus horizon, and increases noticeably in the illuvial horizon. The weakening of the eluvial process must necessarily lead to a sharp decrease of the humus content in the B horizon and its accumulation in the now almost dead A_2 horizon as a result of the propagation of root systems in it. Let us note the humus profile of peichiang-tu (Table 1) is not characteristic for podzolic or gray forest soils and only slightly resembles the humus profile of solods.

The decomposition of plant residues under reducing conditions in meadow soils with a whitish horizon is accompanied primarily by the formation of substance of the fulvic acid group

---

[3] The mineralogical analysis of the fine fractions was made at the Chair of Soil Science of the Moscow State University under the supervision of N. G. Zyrin.

[4] The clay contains exchangeable sodium at a depth of 1-2 m. The horizons at this depth, which are considered by most authors as parent materials, show clear signs of the development of soil-formation processes, which could be associated with the appearance of exchangeable sodium here.

Table 1

Humus, pH, and exchangeable aluminum in soils with a whitish horizon and in dark meadow soil

Profile No.	Soil and profile location	Depth, cm	Humus, %	pH		Al	
				Water	Salt	Meq	% of total
1707	Thick, dark meadow soil (22). Zeya-Bureya plain	0—12	8,4	5,9	5,1	0,10	0,2
		20—30	3,4	6,1	3,4(?)	0,04	0,1
		50—60	1,3	6,2	4,9	0,14	0,5
		90—100	0,5	6,1	4,6	0,43	1,6
		170—180	—	6,3	4,6	0,35	1,4
1484	Dark meadow soil with strong residual solodization (22). Same	0—10	4,4	6,1	4,6	0,06	0,3
		20—30	0,7	5,9	4,2	0,75	4,8
		40—50	1,5	5,8	4,1	1,42	6,3
		70—80	0,8	5,8	4,1	1,26	4,5
		110—120	—	5,8	4,4	0,16	0,6
		150—155	—	5,9	4,6	0,16	0,5
522	Light-gray solodized soil (921). Khanka plain	0—10	6,5	6,6	—	—	—
		15—25	0,7	6,0	—	1,58	7,3
		40—50	1,6	5,8	—	4,27	12,6
		70—80	1,2	5,9	—	3,70	9,0
		105—110	0,1	5,9	—	1,60	3,7
1	(19) Amur-Ussuri plain	0—7	7,1	5,9	4,5	0,05	0,2
		12—20	1,7	4,9	3,5	3,36	30,0
		25—35	0,9	4,9	3,4	4,04	33,9
		40—50	0,6	4,9	3,3	4,21	34,2
		95—105	0,6	4,9	3,7	1,49	6,7
		135—145	—	5,5	4,4	0,12	0,6
		210—220	—	5,9	4,9	0,03	0,1
532	Meadow soil with a whitish horizon. Amur-Ussuri plain	0—5	6,0	5,5	4,6	0,16	0,7
		10—15	2,2	5,8	4,2	1,99	20,5
		21—31	0,8	5,5	4,2	3,38	32,5
		41—51	—	5,4	4,2	5,40	18,0
		120—125	—	5,8	5,1	0,17	0,7
225	Northern variety of soils with a whitish horizon. Zeya-Amur interfluve.	0—5	5,3	6,2	5,3	0,05	0,2
		5—11	0,6	5,6	3,9	1,95	17,4
		30—40	—	5,3	3,8	1,93	13,4
		50—60	—	6,3	4,6	0,63	4,0
		112—122	—	6,3	4,9	0,04	0,2
		130—145	—	6,7	5,2	0,04	—

Note: Comma represents decimal point.

(30, 22). Fulvic acids play the main part in peptization and in the transportation of soil formation products in the profile, which is confirmed by the high content of these compounds in the humus-illuvial horizon (22).

The nature of the eluvial process in various soils depends on a number of factors, first of all on the reaction of the medium. Investigators who pointed to podzol formation or solodization as a form of the eluvial process in Amur soils with a whitish horizon, believed at the same time that clay minerals break up in the eluvial horizons and partly resynthesize in the B horizon. According to modern views, there is a close relationship between the stability of minerals and the reaction of the medium. Clay minerals begin to break up at a pH of 5.4 and break up rapidly at a pH below 5 (39). In peichiang-tu the pH of water suspensions drops to below 5 only in the A_2B and B horizons of comparatively well-drained soils in forests on slopes (31, 32), while the reaction of meadow soils is slightly acid or neutral.

Fridland (29) showed that the chemical composition of the clay fraction of soils with a whitish horizon (Khabarovsk area) is approximately the same along the entire profile, in spite of the intensity of the eluvial process. He relates peichiang-tu to "illimerized" soils, characterized by the removal of colloidal particles as such, without their being decomposed. These conclusions were confirmed by micromorphological investigations (33), which showed that the coatings on the faces of structural units in the B horizon are represented by oriented aggregates of an ironized clay mineral.

However, according to the results of mineralogical investigations of the clay and colloidal fractions (Table 2)[5], the eluvial-illuvial processes in peichiang-tu are accompanied by changes in the composition of minerals of fine fractions along the soil profile. Minerals of the montmorillonite group and magnesian minerals disappear in the eluvial horizon (19), or their amount decreases sharply. The main mass of the minerals of fine fractions is represented by kaolinized hydromicas. If montmorillonite is preserved in the upper part of the profile, it concentrates in the clay fraction and is absent in the colloidal fraction. According to the data of Kurtesov (20), colloidal material proper is most intensely removed from the eluvial horizon. Consequently, during the removal of fine particles in peichiang-tu a differentiation by size and mineral composition occurs within the fraction <0.001 mm in diameter.

The removal of colloids is not the only form of eluviation in the foregoing soils. Data on the composition of natural waters in the region occupied by peichiang-tu point to the essential role of the migration of ionic elements in the development of soil formation. In particular, the silica content in the waters reaches 5-16 mg/l and more. The corrosion of diatom skeletons is an evidence of the high migration capacity of silica in the slightly acid medium of the upper soil horizons. A high silica content was found in the ash of meadow vegetation, which determines the accumulation of phytolitharia in the upper soil horizons (22). The so-called "amorphous silicic acid," extracted from the upper horizons of peichiang-tu (21, 31), apparently represents biogenic opal, which is generally characteristic of hydromorphic soils (2, 28).

The specificity of eluvial processes in the foregoing soils is clearly shown by total chemical and general analyses (21, 22, 29, 31, 10, 16, 27, etc.). A characteristic feature of peichiang-tu is the high mobility of aluminum, usually exceeding the mobility of iron,[6] which is unusual for fine-textured soils with developed reducing processes. It is determined by: 1) the intensity of the movement of aluminum in the clay minerals; and 2) the sharp decrease of the removal of iron from the whitish horizon as a result of the redistribution of iron within the horizon and its fixation in the form of concretions.

Table 2

Mineralogical composition of the fine fractions of soil with a whitish horizon from the Ussuri River valley, village of Zabaykal'skoye. Profile V-5[a]

Horizon	Depth, cm	Particles 1-0.3 μ in diameter	Particles < 0.3 μ in diameter
A_1	0—5	Hydromica (much), kaolinite, halloysite, amorphous silica (diatom skeletons), a little amorphous matter	Hydromica, kaolinite, amorphous substance
A_2	15—25	Hydromica, kaolinite, considerable amount of a montmorillonite mineral (poorly crystallized), little quartz, amorphous substance, aqueous iron oxide	Hydromica, little of a montmorillonite mineral, kaolinitic mineral (little), amorphous substance, iron hydroxides
C	180—190	Hydromica, little kaolinite, much of a montmorillonite mineral, polyskorite	Hydromica, a poorly crystallized montmorillonite mineral, kaolinite (very little), amorphous substance, iron hydroxide

[a] The samples were collected by the correspondent of the Academy of Sciences of the USSR, V. A. Kovda and by Professor Sung Ta-ch'eng. The mineralogical analysis was made under the supervision of Docent N. G. Zyrin at the Chair of Soil Science of Moscow State University, using x-ray, thermal, and electron-microscope methods.

---

[5] Part of the data was published earlier (19).

[6] We do not give the results of total chemical and particle-size analyses of the soils here, since they proved to be similar to those published earlier by other investigators (10, 16, 17, 21, 22, 26, 29, 30, etc.).

Table 3

Chemical composition of natural water in the region occupied by soils with a whitish horizon, mg/l

Place	pH	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+	Sum of ions	SiO_2	Fe_2O_3
Amur River, Khabarovsk	6,6	55,7	3,7	3,2	4,0	5,6	6,6	3,9	82,6	10,5	0,5
Ussuri River, Kazakevichevo	—	33,0	4,7	1,1	6,8	1,8	3,6	1,0	52,0	—	—
Sunguri Riv., mouth	—	61,0	5,9	3,6	13,4	2,9	8,0	2,0	96,8	16,1	0,5
Bog water, surface	6,4	63,4	2,5	Not det'd.	8,2	5,2	4,3	3,2	96,8	5,3	0,5
Ground water from a depth of 1.5 m	6,8	73,2	5,1	31,1	11,8	7,6	16,5	1,0	146,3	10,7	0,5
Well, 3 m deep, Birobidzhan	6,6	58,6	11,2	Not det'd.	15,6	—	8,8	5,8	100,0	5,3	1,5
Well, Jaoho	—	90,0	5,9	1,0	12,0	5,1	12,5	3,6	130,1	—	—

Note: Comma represents decimal point.

A. P. Kurtesov (20) found that the sand fraction in the whitish horizons consists almost entirely of manganese-ferric concretions. Roslikova (26) showed that the principal mass of concretions accumulates precisely in the whitish horizon (up to 16%-17% of the soil weight); their amount decreases sharply in the humus horizon (down to 3%-6%) and in the B horizon (less than 1%). The morphological correspondence between the degree of lightening of the eluvial horizons and the accumulation of concretions in them is an evidence of the deciding role of the process of segregation of iron in concretions, initially distributed in the mass of the forming whitish horizon. The accumulation of concretions is a sure indication of sharp changes in the oxidation-reduction regime of soils (7, 34, 37).

Great changes in the adsorption complex are closely related to the development of the eluvial process. In particular, the content of exchangeable aluminum increases considerably and may reach 75% of the total cations in the A_2 horizon (27). The absolute content of exchangeable aluminum reaches a maximum in the A_2B horizon. One of the sources of exchangeable Al^{+++} may be the aluminum of the octahedral layers of the clay mineral lattice. As the whitish horizon forms, the surface of these layers becomes purified of iron hydroxide films, which facilitates the removal of aluminum to neutral salt solutions.

The sharp difference in the pH of the water and salt suspensions in the A_2 and A_2B horizons is associated with the high content of exchangeable aluminum. The content of exchangeable aluminum (Table 1) in the peichiang-tu profile is specific and different from that in podzolic soils and solods.

Alkali earth bases in the exchangeable and silicate forms are intensely removed from the upper part of the profile. At the same time potassium and sodium are comparatively stable in the soil profile (21, 22, 29) and may even accumulate in the A_2 horizon (21, 9a).

The joint presence of sodium, potassium, and hydrogen (aluminum) in the adsorption complex in peichiang-tu was first noted by Vil'yams (4). The sodium content in meadow peichiang-tu is usually about 1-2 meq/100 g of soil. Only in the soils of the southern part of the Khanka plain does it increase to 9 meq (13% of the sum of cations) (21, 31). Only traces of exchangeable alkali bases were found in forest soils on slopes (31).

The problem of exchangeable potassium has been more or less clarified since mineralogical investigations showed that the fine fractions consist primarily of hydromica. As far as the role of sodium in the formation of peichiang-tu is concerned, it deserves special attention. Available data indicate that exchangeable sodium is relatively stable in the eluvial horizon (as compared to alkali earth cations) as a result its content (in percent of the sum of cations) in the A_2 horizon may be the highest in the entire profile (Table 4). Moreover, there is a possibility for not only the relative, but also the absolute accumulation of exchangeable sodium in the upper soil horizons (14, 26). The presence of exchangeable sodium in peichiang-tu and its increased content in the eluvial horizons are apparently the result of the soil-formation process itself. As we know (2, 6, 35) the opposite is characteristic of solods.

The causes and forms of sodium accumulation in the adsorption complex are unknown. The assumption that the soil-forming parent material is solonetzic (21, 22), has not been confirmed by analytical data yet. The characteristics of the behavior of exchangeable sodium in the eluvial horizon during the relative increase or stabilization of its total content, give reasons to believe that there is a relationship between the exchangeable sodium and the primary minerals containing this element. This

Table 4

Exchangeable sodium in soils with a whitish horizon and in dark meadow soil

Profile No.	Soil	Depth, cm	Sum of adsorbed cations	Na^+, meq	Na, % of sum
1707	Thick, dark meadow soil (22)	0—12	47,1	0,43	1,0
		20—30	31,9	0,45	1,4
		50—60	27,2	0,65	2,2
		90—100	26,5	0,65	2,2
		170—180	25,5	0,70	2,5
1484	Dark meadow soil with strong solodization—podzolization (22)	0—10	23,3	0,43	1,8
		20—30	15,8	0,43	2,7
		40—50	22,5	0,43	1,9
		70—80	28,0	0,69	2,5
		110—120	28,9	0,67	2,4
		150—155	30,4	0,70	2,3
21	Meadow soils with signs of water-logging (26)	0—14	—	1,27	—
		14—23	—	0,4	—
		23—39	—	1,8	—
		39—53	—	2,2	—
		53—63	—	1,9	—
		75—85	—	1,7	—
		110—120	—	1,3	—
		170—180	—	1,1	—
532	Meadow soil with a whitish horizon, Amur-Ussuri plain	0—5	22,8	0,53	2,3
		10—15	9,7	0,63	6,5
		21—31	10,4	0,93	9,0
		41—51	29,7	0,96	3,2
		120—125	26,1	1,49	5,7
14	Peichiang soil (17)	1—9	45,1	0,16	0,4
		9—19	8,0	0,16	2,0
		20—30	4,5	0,32	7,1
		45—55	13,5	0,32	2,4
		90—100	20,2	0,64	3,2
		130—140	28,1	0,96	3,4
		200—210	25,1	0,96	3,8

Note: Comma represents decimal point.

complicated problem requires further study. Some investigators (1, 2) believe that the adsorbed sodium is the result of the migration of very mobile sodium salts in soils during the dry spring period. According to the investigations of Yarkov, Kaurichev, and Poddubnyi (35), exchangeable sodium stimulates the development of reducing processes in soils.

In the driest southwestern part of the Khanka plain (Mo River valley) there are meadow soils with a whitish horizon. The eluvial portion of the profile has a neutral reaction (about 6.5), carbonates separate from a depth of 30-40 cm, and the content of exchangeable sodium is high (21, 26, and others). Fulvic acids predominate in the composition of humus (30). The specificity of these soils is associated with the dryness of the local climate (relative to its monsoonal nature). But even here, according to the opinion of Yaroshenko (36), the variable oxidation-reduction regime is the cause of the development of the eluvial process. The conclusion of Yaroshenko is substantiated by direct observations: the formation of the whitish eluvial horizon was traced in the water-logged soils of the Mo River terraces as the region was drying out in the course of about 10 years. Judging from all their characteristics, the foregoing soils, developing under conditions of shallow mineralized ground-water depths, are close to solods, and probably represent an environmental subgroup of the latter, linking the solods of continental areas to peichiang-tu in the environmental series.

We must mention another characteristic feature of soil formation in the Amur region. The presence everywhere of a temporary water table close to the surface (1-2 m), determined by climatic characteristics and the nature of the materials (17, 18). The recharge of the soil profiles by rising flow of soil solutions during dry periods creates conditions for the hydrogenic accumulation of dissolved compounds (19). However, hydrogenic accumulation is superimposed by a strong eluvial process in peichiang-tu in contrast to dark meadow soils, and apparently is of certain importance only in the lower part of the soil profile.

The common features of the formation of various soils with a whitish horizon in the plains of the Amur region include:

1) the formation of a shallow eluvial-accumulative humus horizon, with predominantly mobile compounds of the fulvic acid type in the composition of humus;

2) the formation of a thick whitish eluvial horizon as a result of a number of individual processes: a) the differential removal of clay minerals under the protection of humic substances; b) the removal of the decomposition products of minerals and ash elements in the ionic or colloidal form; c) the segregation of iron and manganese concretions within the whitish horizon, possibly, with a certain addition of these elements from the outside, and, correspondingly, d) profound changes of a specific nature in the composition of adsorbed cations (loss of calcium and magnesium, stability or accumulation of sodium, and the appearance of huge quantities of exchangeable aluminum);

3) partial accumulation of compounds, removed from the upper part of the profile, in the illuvial horizon.

None of these processes, taken individually, is specific for peichiang-tu. However, the intensity of the processes, their individual characteristics, and their relationships lead to the formation of special soils, reflected in a number of static physicochemical and chemical characteristics. Further, it must be emphasized that the climatic characteristics of the Amur region give reason to believe that the dynamics of soil formation in the course of the year are quite specific, differing from those of podzolic and solodized soils.

Because of the characteristics of Amur soils with a whitish horizon we have reason to relate them to the group of oceanic environmental soils of continents, characterized by the removal of clay minerals without substantial changes in their crystal lattice and a special form of iron migration and accumulation, as the most specific and at the same time the most common aspects of soil formation. Such soils were first put into an individual genetic category by Krauss (37) who called them "gley-like" soils. Later they were called "pseudogley" (40). These terms were proposed in order to distinguish soils with temporary surface gleization from soils with a stable surface and ground-water gleization (38, 40). These terms were apparently suggested to separate soils with "gley" (5), a product of reducing processes under definite conditions, from soils in which reducing processes do not lead to the formation of "gley." It is apparently being assumed that reducing processes and gleization processes are not synonymous.

The foregoing material and data from the literature (34, 35, etc.) show that the development of the eluvial process in soils with excessive moisture depends on the duration of oxidation and reduction conditions in soil horizons and the possibility of the removal of the products of soil formation in the active part of the profile. Mineral soils, excessively moistened by fresh water, may be divided into several groups on the basis of the foregoing:

I. Soils in which reduction processes take place under conditions of stable excessive moistening by stagnant water. The removal of the products of soil formation from the sphere of reaction is extremely difficult. The gley horizons differ little from the parent material, a fact which is confirmed by investigations of excessively moist soils under conditions of poor drainage (11, etc.)

II. Soils in which reduction processes take place under condition of temporary excessive wetting by flowing waters. The products of soil formation are more or less fully removed from the sphere of biochemical and physiochemical processes, which leads to a profound change in the parent material during soil formation. Here we must distinguish two cases: a) reduction processes, predominating in time, which are periodically replaced by oxidation processes. The products of soil formation are removed by lateral or vertical moisture flow. A characteristic feature of the eluvial process under such conditions is the high mobility of iron and a relative inertness of aluminum (5, 9a, 3, etc.); b) oxidation processes, predominating in time, which are periodically replaced by intense reduction processes. The products of soil formation are removed from the sphere of reactions in two ways: 1) removal beyond the limits of the profile; and 2) segregation within the profile and fixation in relatively inert forms. Profound changes in the parent material and the formation of a sharply differentiated profile are unavoidable. A diagnostic feature of the eluvial process under these conditions is the high mobility of aluminum, along with iron, as it occurs in podzolic soils. When the segregation of iron compounds (and manganese) is intense, the mobility of the latter, as determined from the results of total chemical analyses, may be several times lower than that of aluminum, exactly what we have in peichiang-tu.

We will not examine cases of the development of reduction processes in soils forming under conditions of stable excessive wetting by flowing waters and temporary excessive wetting by stagnant waters.

Far Eastern soils with a whitish horizon can be characterized as variable-gleyey eluvial, genetically related to podzolic soils and solods, but sufficiently different from them.

Liverovskiy and Rubtsova (23, p. 67) tried to separate peichiang-tu in the form of a new group, including the soils of the Amur-Ussuri depression, under the name "meadow-gleyey soils." The authors considered the eluvial process, inherent to soils with a whitish horizon, as 1) podzolization, 2) solodization, and 3) as a "peculiar variable-gley process," thus distinguishing three different types of eluvial process in morphologically and chemically related soils forming within the limits of one and the same climatic region.

Podzol formation can hardly play an individual role in the formation of soils in the plains of the Amur region. Under conditions of the transition to Siberia, the climate is not the same as the moderately-continental climate of the western half of Eurasia to which podzolic soils proper are confined. Soils with weakly pronounced features of southern peichiang-tu, having a slightly acid reaction (see Profile 225, Table 1) were also found in the Amur region on fine-textured parent materials of the Amur-Zeya interfluve and the northern portions of the Amur-Ussuri depression.

Certain features of peichiang-tu actually bring these soils close to solods. But the authors of the foregoing paper (23) note that "solodized" soils are morphologically identical to "meadow-gleyey" and "brown, deeply podzolized" soils, and mention the presence of exchangeable sodium as a single chemical characteristic.

In our opinion, the process of formation of Amur soils with a whitish horizon must be separated from podzol formation and solodization. The name "meadow-gleyey" soils (23) does not reflect the eluvial process, which is the most important aspect of the given soil formation. The special nature of the meadow process, inherent to the soils of the Amur region, was stressed by Kovda, Liverovskiy, and Sung Ta-ch"eng (19). The peculiar reduction processes in these soils, which are not similar to gleization processes, were mentioned by us earlier.

Because of the wide distribution of peichiang-tu in the Soviet Far East, we must find a name for it which would be convenient to use and reflect, as usual, the color of the soil. We propose to retain the popular Chinese name for meadow soils with a whitish horizon, which properly reflects the color of the whitish horizon when it is brought to the surface by a plow and dries, and to use it in the Russian translation as "bleached meadow" soil.

Bleached soils have a low fertility. According to field experiments (by Chinese scientific institutions), their fertility is 40% of the productivity of meadow chernozems, the best soils of the Amur region. This increases to only 70% in pot experiments. The principal negative property of these soils is their unfavorable moisture regime: desiccation in spring and excessive wetting in mid- and late summer. The melioration of these soils must include their drainage and aeration, together with moisture conservation and irrigation (24, 25). The requirement of these soils in chemical fertilizers is sufficiently specific: a severe deficit of phosphorus with sufficient potassium, and a positive reaction to the addition of copper fertilizers (data of A. A. Budakova).

Bleached meadow and similar soils with a whitish horizon in the forest (bleached forest-soils?) can be used under dry land crops (soya, kaoliang, green bristle grass, corn, and wheat), as well as under rice. The combination of these two possibilities of utilizing soils with a whitish horizon, depending on their properties and their location along the relief, would make it possible to utilize more fully the area of white soils and to differentiate more clearly between methods of reclaiming these soils.

Received February 19, 1960

BIBLIOGRAPHY

1. ALEKSANDROVA, L. N. 1930. Effect of irrigation water in rice plantations on the chemistry of clayey-podzolic soils of the Maritime Province regional experiment station. Tr. opytn. uchrezhdeniy DVK. No. 1. Vladivostok.

2. BAZILEVICH, N. I. 1947. Materials to the problem of the genesis of solods. Pochvovedeniye, No. 4.

3. VERIGINA, K. V. 1953. Characterization of soil gleization processes. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 41.

4. VIL'YAMS, V. R. 1951. Report on the field investigation of soils in the Birobidzhan rayon of the Far East Province. Collected works. Vol. 8.

5. VYSOTSKIY, G. N. 1905. Gley. Pochvovedeniye, No. 4.

6. GEDROYTS, K. K. 1926. Solodization of soils. Tr. Nosovskoy s.-kh. opytnoy st. No. 44.

7. GEMMERLING, V. V. 1922. Certain data for the characterization of podzolic soils. Russkiy pochvoved. No. 4-5.

8. GERASIMOV, I. P. 1959. Gleyey pseudo-podzols of Central Europe and the formation of two-membered mantle deposits. Izv. Akad. Nauk SSSR, ser. geogr. No. 3.

9. GLINKA, K. D. 1910. Brief summary of data on the soils of the Far East. St. Petersburg.

10. GLINKA, K. D. 1911. Problem of the distinction between the podzolic and the bog types of weathering. Pochvovedeniye, No. 2.

11. GORBUNOV, N. I. 1959. Mineral composition and physico-chemical properties of soils in the Amur region. Dokl. na III ses. Soveta po probleme Amura. Moscow.

12. DOSMANOVA, O. P. 1934. Materials for the study of processes of gley formation. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 9.

13. ZAYTSEV, I. K., M. S. GUREVICH, and YE. YE. BELYAKOVA. 1956. Hydrochemical map of Siberia and the Far East.

Izd. Akad. Nauk SSSR.

14. IVANOV, G. I. 1959. Soils of the Khanka plain and the Ussuri River valley, their reclamation and utilization. Dokl. na III ses. po probleme Amura. Moscow.

15. IVANOV, G. I. 1955. Soil conditions in the southern Maritime Province in relation to the growing of ginseng. Dissertation. Pochv. in-t Akad. Nauk SSSR.

16. IVANOV, D. V. 1897. Principal features of the orogeological structure of the Sikhote-Alin range. Zap. Priamurskogo otd. RGO. 1(3). Khabarovsk.

17. KACHIYANI, A. I. 1954. Soils of the agricultural regions of the Far East. Khabarovsk.

18. KOVDA, V. A. 1959. Outlines of the nature and soils of China. Izd. Akad. Nauk SSSR.

19. KOVDA, V. A., YU. A. LIVEROVSKIY, and SUNG TA-CH'ENG. 1957. Outline of the soils of the Amur region. Izvestiya Akad. Nauk SSSR, ser. biol. No. 1.

20. KOVDA, V. A., B. A. ZIMOVETS, and A. G. AMCHISLAVSKAYA. 1958. Hydrogenic accumulation of silica compounds and sesquioxides in the soils of the Amur region. Pochvovedeniye, No. 5.

21. KURTESOV, A. P. 1948. Colloidal-chemical properties of sod-podzolic soils of the Maritime Province and the effect of mineral fertilizers. In the book: Sb. nauchn. rabot s.-kh. opyt. uchrezhdeniy Primorskogo kraya. No. 1.

22. LIVEROVSKIY, YU. A. 1947. Soils of the Amur forest steppe. Pochvovedeniye, No. 7.

23. LIVEROVSKIY, YU. A. and L. P. RUBTSOVA. 1956. Soils of the Seya-Bureya plain and the problems of their genesis. Pochvovedeniye, No. 5.

24. LIVEROVSKIY, YU. A. and L. P. RUBTSOVA. 1959. Classification scheme for the soils of the plain regions of the Far East. Pochvovedeniye, No. 4.

25. Soils of the Amur region, their utilization and melioration. 1957. Edited by V. A. Kovda. Manuscript. SOPSa.

26. PUSTOVOYTOV, N. D. 1959. Meliorative properties of soils in the Amur region. Dokl. na III ses. Soveta po probleme Amura. SOPSa.

27. ROSLIKOVA, V. I. 1958. Certain characteristics of meadow soils in the Amur Region. Pochvovedeniye, No. 5.

28. SUNG TA-CH'ENG. 1959. Soils of the basin of the Amur River and their agricultural reclamation. Dokl. na III ses. Soveta po probleme Amura. SOPAa.

29. TYURIN, I. V. 1937. Biological accumulation of silicic acid in soils. Probl. sov pochvoved. Sb. 4.

30. FRIDLAND, V. M. 1958. Podzolization and illimerization. Pochvovedeniye, No. 1.

31. KHAVKINA, N. V. 1958. Organic matter in the soils of low river terraces in the Khanka plain. In the book: "Tezisy dokl. na I Delegat. s"yezde pochvovedov". Sektsiya genezisa i klassifik. pochv.

32. KHANTULEV, A. A. 1956. Materials for the characterization of soils in the agricultural areas of the Maritime Province. Uch. zap. LGU, No. 221, ser. biol. i n. No. 36.

33. TSYGANENKO, A. F. 1954. Certain data on soil formation and weathering in the Southern Maritime Province. Uch. zap. LGU, No. 174, ser. biol. i n. No. 36.

34. YARILOVA, YE. A. and YE. I. PARFENOVA. 1957. Newly-formed clay minerals in soils. Pochvovedeniye, No. 9.

35. YARKOV, S. P. 1954. Formation of podzolic soils. Dokl. na V Mezhd. kongr. pochvovedov. Izd. Akad. Nauk SSSR.

36. YARKOV, S. P., I. S. KAURICHEV, and N. N. PODDUBNYY. 1956. Experimental study of the genesis of solonetzes and solods. Izv. TSKHA. No. 2.

37. YAROSHENKO, P. D. 1956. Problem of the genesis of vegetation and soils in the Khanka plain. Voprosy sel'sk. i lesn. khoz. Dal'nego Vostoka. No. 1.

38. KRAUSS, C. and others. 1939. Standartsgemässe Durchführung der Abkehr von der Fichtenwirtschaft im Nordwestsächischen Niederland. Reprint from: Tharandter Forstlichens Jahrbuch. 90 (7/9).

39. KUBIENA, W. L. 1953. Bestimmungsbuch und Systematik der Böden Europas. Stuttgart.

40. LAATSCH, W. 1957. Dynamik der mitteleuropäishcen Mineralböden. Dresden and Leipzig.

41. MÜCKENHAUSEN, E. 1956. Die Einteilung der wasserbeinflussten (hydromorphen) Böden Deutschlands. Rapports (VI-e Congr. International de la science du sol. Paris, 1956). Vol. E (Com. 5).

FORMS OF ACCUMULATION AND MIGRATION OF SUBSTANCES IN BOG SOILS

V. N. YEFIMOV, Leningrad Agricultural Institute

Bog soils occupy large areas in the taiga zone and have long attracted attention. Huge amounts of organic matter, rich in nitrogen, accumulate in them. The interest of soil scientists in the study of bog soils has increased even more in the last 10 years as a result of the reclamation of bog soils and the use of peat for fertilizer.

The conditions of water-logging are well-known from the works of Sukachev (12), Dokturovskiy (5), Tanfil'yev (13), and Tyuremnov (14), but the forms of accumulation and migration of substances in these soils have been studied little yet. One of the main reasons for this is the almost complete lack of unified analyses of the system: peat producers — peat soils — soil water, whereas there is a huge amount of unrelated analytical data on peat.

There are only a few works devoted to the study of bog and podzolic-bog soils in which unified analysis is used to a certain extent to solve various problems (3, 6, 7, 8, 9, 10, 11). It was used most fully and thoroughly by Verigina (4), when studying the processes of iron migration and accumulation.

The literature still contains few works which examine the accumulation and movement of substances in various peatbeds and the forms of their accumulation and migration. The method of unified analysis is used in the present paper to solve these problems.

We studied the following peat soils:

1. Upland cottongrass-sphagnum soil with a layer of peat dust more than 1 m thick. The peat is underlain by morainic clay. The peatbed is located in the forest recreation area Tarasary of the Leningrad Agricultural Institute. The thickness of the peat varies from 2.5-3 m. The peatbed is completely saturated with water during wet years, while the water drops to a depth of 80 cm in dry years.

2. Transitional maritime peat soil on cottongrass-brushwood peat, formed on a two-membered deposit in the Neva depression in the immediate vicinity of the Baltic Sea. It is located in the territory of the experimental farm of the Northern Scientific-Research Institute of Hydraulic Engineering and Melioration, near the Volodarskaya railroad station. The peat is moderately decomposed and 55-70 cm thick. The ground water is located in the sand layer on varved clay at a depth of 50 cm.

3. Transitional soil on cottongrass-sphagnum peat with scattered brushwood. The peatbed is formed on morainic clay containing limestone fragments and is located in the territory of the educational-experimental farm of the Leningrad Agricultural Institute near the village of Kondakoshino. The peat is 60-70 cm thick, and it is only very slightly decomposed, except for the lowermost layer. Samples were taken when water was at a depth of 40 cm.

4. Lowland maritime peat soil on sedge-reed peat, formed on calcareous tuff in an area occupied by the eroded clint of a Siliurian plateau (15). The peat is highly decomposed. The peat horizon is 1 m thick. When the samples were taken the ground water was at a depth of 50-60 cm.

5. Lowland peat soil on sedge-wood peat formed on calcareous tuff under the original bank of the Luga River in the territory of the "zvezda" kolkhoz, Luga rayon. The peat is 1 m thick and highly decomposed. When the samples were taken the ground water was at a depth of 50-60 cm.

When selecting the samples, the following conditions were adhered to.

1. The peat deposits were sufficiently homogeneous and did not contain the remains of stumps, sandy, clayey, and other layers. All the peatbeds were formed during the postglacial period.

2. The degree of decomposition of peat in every peatbed gradually changed with depth.

3. The botanical composition of peat was identical to the composition of present peat-producers.[1]

---

[1] The botanical composition of peat in lowland peatbeds was not determined because of its high degree of decomposition throughout the profile.

Table 1

Total composition of peat-producers and peat soils

Sample of vegetation and peat soil	Depth, cm	Saline pH	Raw ash, of dry matter	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3
				in % of ash						
Upland										
Eriophorum vaginatum — 10% Sphagnum tuscum + + ambiyph. — 90%		Not det'd.	3,76	51,57	5,35	6,49	0,35	10,11	7,56	5,18
Peat	0—20	3,0	2,94	54,03	5,83	12,12	0,11	9,46	3,38	6,85
	20—40	3,0	2,03	54,65	4,58	14,93	0,11	9,25	3,32	7,28
	40—60	3,0	1,06	39,23	7,86	14,76	0,41	15,55	5,00	9,24
	60—80	3,4	0,96	32,35	8,83	14,30	0,49	19,25	7,64	8,32
	80—100	3,4	1,10	21,89	14,59	11,60	0,43	21,30	6,31	8,73
	100—120	3,4	0,86	17,88	22,26	9,83	0,31	25,03	6,45	7,66
	120—140	3,6	1,12	15,29	18,18	13,09	0,14	25,83	6,17	7,46
Transitional										
Eriophorum vaginatum — 20% Sphagnum magllan, Centrale, opiculat. — 80%		Not det'd.	4,69	42,67	6,11	7,66	0,39	10,71	6,53	4,96
Peat	0—10	4,7	6,56	59,56	10,28	13,78	0,09	5,78	2,03	4,39
	10—20	4,7	4,42	52,74	11,53	4,00	0,12	5,85	1,63	5,38
	20—30	4,7	4,44	22,44	14,78	27,11	0,09	14,38	4,21	7,36
	30—40	4,7	3,35	14,60	23,83	25,62	0,05	14,99	4,34	7,44
	40—50	4,7	5,90	15,37	24,90	25,25	0,03	16,06	4,59	8,61
Transitional maritime										
Eriophorum vaginatum — 90% Birch leaves 10%		Not det'd.	3,44	24,89	5,91	5,27	0.62	18,49	7,00	6,59
Peat	0—10	4,2	14,74	52,73	10,17	15,23	0,35	1,71	0,83	5,43
	10—20	4,2	6,07	42,87	18,53	17,58	0,20	6,38	1,10	6,50
	20—30	3,6	4,34	27,20	28,53	20,54	0,40	6,79	2,05	10,52
	35—45	3,6	8,65	27,67	39,01	9,13	0,07	4,38	1,32	10,85
Lowland										
Eguisetum palustr. — 30% Carex vulpina — 30% Aulocomnium palusche — 30% Willow, birch, and alder leaves 10%		Not det'd.	5,83	32,02	4,94	5,11	0,42	22,61	8,12	5,22
Peat	0—5	6,6	18,47	14,52	38,97	3,79	0,02	25,02	3,02	2,64
	5—15	6,5	47,28	5,72	83,14	2,04	Trace	6,21	1,21	0,96
	15—25	6,6	29,51	9,02	70,21	2,11	"	11,21	1,57	2,40
	25—35	6,6	28,51	8,96	70,50	2,11	"	12,64	1,55	3,25
	35—45	6,6	26,07	8,28	70,28	3,12	"	13,87	1,63	3,19

Table 1 (continued)

Sample of vegetation and peat soil	Depth, cm	Saline pH	Raw ash, of dry matter	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3
				in % of ash						
	45—60	6,6	18,64	6,16	43,04	2,20	Trace	25,69	2,61	6,83
	60—70	6,8	17,77	11,87	17,87	19,36	0,27	40,67	3,29	7,20
	70—80	6,8	18,42	8,90	25,56	5,19	0,14	33,26	2,71	10,37
	80—90	6,8	16,71	4,50	21,27	3,27	0,12	36,78	2,35	13,93
				Lowland maritime						
Carex gracilis — 40% *Phragmites communis* — 60%		Not det'd.	6,15	32,10	0,53	0,57	0,91	8.83	5,39	6,10
Peat	0—10	6,8	26.36	32,82	3,06	0,21	0,23	31,62	4,15	7,80
	10—20	6.8	21,84	34,05	2,18	9,57	0,87	30,25	4,87	7,20
	20—30	6,8	19,45	29,12	3,37	6,18	1,01	33,75	4,92	10,20
	30—40	6,8	17,51	12,48	11,30	1,28	0,17	43,85	5,70	15,43
	40—50	6,8	16,56	4,10	11,44	3,08	0,18	48,35	5,86	20,82
	50—60	6,8	18,15	3,60	6,36	8,21	0,28	48,90	8,20	18,78
	60—70	7,1	23,15	3,34	7,50	2,44	0,16	49,10	3,44	20,36
	70—80	7,0	22,56	2,98	8,36	1,68	0,36	41,89	4,17	21,54
	80—90	6,8	17,60	4,15	11,52	2,01	0,30	35,52	5,00	29,52
	90—100	6,8	17,99	3,40	11,62	2,56	0,23	35,84	5,20	29,57

Note: Comma reprèsents decimal point.

Peat soil samples were collected and analyzed layer by layer in the entire peat horizon. Simultaneously we studied the ash composition of peat-producing plants and the composition of soil water. The results are given in Table 1.

Without examining the results in great detail let us note that upland peat soil has a very low ash content, lowland peat soils have a high ash content, and the ash content of transitional peat soils is normal. The only exception is the transitional maritime peat soil, where the ash content increases in the upper 10 cm of peat as a result of a small layer of water-deposited sand. Unfortunately this phenomenon is rather common in maritime peatbeds and we could not avoid it.

When studying the total chemical composition of peat and peat-producers we also determined the composition of bog waters (Table 2).

A considerable amount of the dry residue in water from acid upland and transitional peat bogs is represented by organic substances, while in neutral lowland peat bogs mineral substances predominate in the composition of water. The concentration of mineral substances in the waters of lowland and transitional maritime peatbeds is 10 and more times higher than in the waters of upland and transitional continental peatbeds. The composition of the ignited residue varied in the bogs studied.

In examining the results obtained we compared

Table 2

Composition of bog waters.

Type of peat bog	pH	Dry residue	Ignited residue	C	Fe^{++}	Fe^{+++}	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	SO_3
		g/l		mg/l			in % of mineral portion					
Upland	4,1	0,24	0,02	109	Traces		38,6	3,4	7,7	0,13	11,6	8,3
Transitional	4,8	0,27	0,03	115	"		18,6	9,2	16,6	0,04	25,5	9,5
Transitional maritime	3,3	0,36	0,20	137	34,4	None	8,1	17,2	10,0	0,02	10,4	46,6
Lowland	7,8	0,28	0,17	3,2	Trace		4,1	0,16	0,02	Trace	42,9	9,8
Lowland maritime	7,8	0,87	0,64	7,0	None		1,5	None		"	29,6	49,4

Note: Comma represents decimal point.

the chemical composition of present peat-producers with the composition of peat soils, whereby we took into consideration the concentration of mineral substances in bog waters. In spite of a certain conditionality of similar calculations used by a number of authors (4, 6, 7, 8, 9), we consider it correct to use the method of comparison, proceeding from those conditions which were adhered to in the selection of peatbed. Moreover, we did not take into account the most mineralized layer of peat, lying at the boundary with the underlying parent material, in any of our calculations. Because of the high degree of peat decomposition in lowland peatbeds and the impossibility of determining its botanical composition, we compared the composition of peat-producing plants in the upper 30 cm of the peat soil, assuming that it was formed by present peat-producers and is under the influence of present waters. In general it is difficult to believe that the qualitative composition of waters in upland and transitional peatbeds has changed during different periods of their lives, since they are primarily fed by precipitation.

All these circumstances justify our use of the method of comparing the composition of peat-producers and peat for determining the accumulation and migration of substances when analyzing the results obtained. However, the same reasons do not allow us to extend the results of our investigation to all the various peat bogs encountered in nature.

Upland peat soil. The total ash content of the peat-producing plants and the composition of the ash are typical of sphagnum mosses. The SiO_2 greatly predominates in the composition of the ash, then comes Ca. The sesquioxide, magnesium, and sulfur contents are somewhat low and approximately equal. The ash composition of the upland peatbed differs from the composition of the peat-producing plants. The lower part of the profile is comparatively rich in Fe and Ca and poor in SiO_2. In addition to the pronouncedly uneven distribution of a number of elements in the ash of the peatbed, there is an absolute impoverishment of mineral substances in it. Consequently, in comparing the average indices of the total ash content and the composition of ash in peat-producing plants with that in the peat, we can actually observe the removal of all ash elements:

	Gray ash	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3
	in % of dry mass							
Eriophorum vaginatum — 10% Sphagnum fuscum + + amblyph. — 90%	3.76	1.95	0.21	0.25	0.009	0.38	0.28	0.19
Peat soil[a]	1.49	0.63	0.13	0.19	0.003	0.21	0.07	0.11

[a] Average indices for the homogeneous peat layer.

The degree of removal of the individual elements is determined by the ratio between the composition of peat and the composition of the peat-producing plants.[2]

$$\overset{Al_2O_3}{0.76} < \overset{Fe_2O_3}{0.62} < \overset{SO_3}{0.58} < \overset{CaO}{0.55} < \overset{P_2O_5}{0.33} < \overset{SiO_2}{0.32} < \overset{MgO}{0.24}$$

The Mg, SiO_2, and P are removed with the greatest intensity from the profile of the peatbed, then come S and Ca, while the least mobile are Fe and Al, which is the explanation of their relative accumulation in the ash at certain depths. The impoverishment of the upper part of the profile of upland peat soil results both from the biological absorption of mineral substances by peat-producing plants and from leaching. Removal is also confirmed by the analysis of bog waters.

The leaching of organic substances from the soil is rather considerable. Their concentration in bog waters reaches 110 mg C per liter. The total amount of mineral substances is somewhat small, only 20 mg/liter. The SiO_2 and Ca predominate among the latter. The relatively high amount of P_2O_5 in the water also confirms our conclusion about the removal of mineral substances from the profile of the upland peatbed.

Transitional peat soil. If the total ash content of peat-forming plants in the transitional peatbed somewhat exceeds that of peat-producers in the upland peatbed, their ash composition is the same.

The ash composition of the transitional peat soil, as that of upland peat soil, differs from the ash composition of peat-producing plants. The zone of Fe, Al and Ca accumulation and SiO_2 impoverishment is found in the lower part of the profile. As in the upland peat soil there is also no absolute enrichment of the soil with mineral substances here; there is only a relative enrichment as a result of the removal of a number of elements:

	Gray ash	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3
	in % of dry mass							
Eriophorum vaginatum — 20% Sphagnum magell. centrale apiculat. — 80%	4.60	2.12	0.29	0.37	0.017	0.49	0.29	0.25
Peat soil	4.93	1.72	0.82	0.92	0.003	0.54	0.16	0.32

The ratio of the composition of peat to the composition of peat-producing plants confirms the accumulation of some elements and the removal of others:

$$\underset{\xleftarrow{\text{Accumulation}}}{\overset{Fe_2O_3}{2.82} > \overset{Al_2O_3}{2.48} > \overset{SO_3}{1.28}} \quad \overset{CaO}{>1.10} \quad \underset{\xrightarrow{\text{Removal}}}{\overset{SiO_2}{0.81} < \overset{MgO}{0.55} \; \overset{P_2O_5}{<0.18}}$$

The biological removal and leaching of P, Mg, and SiO_2 take place within the peatbed. The analysis of water confirms this. The amount of

---

[2] A similar method of calculation was used by Rozhnova and Schastnaya (10).

Ca in the profile remains stable. The removal of Ca is apparently compensated for by its addition with soil water from the underlying material containing limestone fragments. The concentration of organic matter in the waters of the transitional peatbed is the same as in the upland peatbed, but there are more mineral substances in the waters of the transitional bog — a concentration of 30 ml/liter[3] (Table 2). The Ca predominates greatly in the ignited residue of the water and since its amount in the peatbed does not decrease as compared with the content of this element in peat-producing plants, we can speak of the addition of this element.

Transitional maritime peat soil. The ash composition of the peat-producing plants of this peatbed differs somewhat from the composition of the ash of peat-producers of the transitional and upland peatbeds. There is almost 2 times more Ca in their ash composition and somewhat less SiO_2 than in the ash of the peat-producers in the transitional and upland peatbeds. Apparently this is attributable to the selective capacity of various types of plants with respect to the absorption of mineral substances. The ash composition is heterogeneous in the peat profile. There are zones of the relative accumulation of iron and sulfur in its lower part. The upper part (0-10 cm) is rich in SiO_2 because of the presence of a thin extraneous sand layer, therefore this part of the profile was excluded when determining the ratio of the composition of peat to the composition of peat-producers. In addition to well-pronounced zones of comparative Fe and S accumulation, there is an absolute enrichment with mineral substances in the peatbed as compared to peat-producing plants:

	Gray ash	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3
				in % of dry mass				
Eriphorum vaginatum — 90% Birch leaves — 10%	3.44	0.89	0.14	0.17	0.024	0.61	0.25	0.22
Peat soil (10—45 cm)	6.35	2.06	1.91	0.91	0.011	0.35	0.09	0.59

The considerable increase of the ash content of peat soil, as compared to that of peat-producers, results from the intense accumulation of Al and, especially, Fe. The S and SiO_2 also accumulation in the peatbed.

$$\underbrace{\overset{Fe_2O_3}{13.64} > \overset{Al_2O_3}{5.35} > \overset{SO_3}{2.68} > \overset{SiO_2}{2.31}}_{\text{Accumulation}} \qquad \underbrace{\overset{CaO}{0.57} < \overset{P_2O_5}{0.45} < \overset{MgO}{0.36}}_{\text{Removal}}$$

The ratio of the composition of the peat soil to the composition of the peat producers points to the considerable simultaneous removal of Ca, P, and, especially Mg from the profile.

The composition of the bog waters of this peatbed showed that the concentration of organic substances is practically the same as in the upland and transitional bogs. The concentration of mineral substances is high, 200 mg/liter (Table 2). Among the latter, two elements predominate sharply: iron (30 mg/liter) and sulfur (more than 90 mg/liter). These data correlate well with the enrichment of the peat with iron and sulfur as a result of their transport by ground waters.

Lowland peat soil. The ash content of peat-producing plants in the lowland continental peatbed is considerably higher than in the peat-producers of upland and transitional peatbeds. The ash is rich in calcium. The peat soil proper is characterized by a very high ash content, especially in the upper part of the profile. Iron reaches huge amounts in the ash from the upper part of the peatbed; in its lower part the sulfur and calcium content increases. This accumulation of substances is of an absolute rather than relative nature. The upper part of the profile represents a mineralized iron layer. The average indices of the total chemical composition of the peat-producers and of the soil are:

	Gray ash	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3
			in % of dry mass				
Equisetum palustris — 30% Carex vulpina — 30% Aulocomnium palustr. — 30% Willow, birch, and alder leaves — 10%	5.83	1.77	0.30	0.40	1.32	0.52	0.27
Peat soil (0—35 cm)	30.94	2.65	21.83	0.72	3.61	0.51	0.64

The ratio of the composition of soil to the composition of peat-producing plants points to the absolute enrichment of the soil with all the ash elements, except for Mg, which is practically stable. Iron accumulates most intensely:

$$\overset{Fe_2O_3}{72.76} > \overset{CaO}{2.73} > \overset{SO_3}{2.37} > \overset{Al_2O_3}{1.80} > \overset{SiO_2}{1.49} > \overset{MgO}{0.98}$$

Such a considerable enrichment of the peat soil with mineral substances and especially Fe and Ca results from their supply by ground waters.

The peat soil may be called calcium-iron soil because of the pronounced accumulation of these substances in its profile. The analysis of water showed that there is practically no leaching of organic substances, while among the mineral substances in the bog water Ca predominates sharply, reaching 70 mg/liter (Table 2).

Maritime lowland peat soil. Even though the total ash content of peat-producing plants in the maritime lowland peatbog is the same as that of peat-producers in the continental lowland peatbed, the ash composition of the former is characterized by low Al and Fe content. The ash content of the peat soil proper is very high and varies along the profile from 20%-26%.

Extremely great changes occur in the ash composition of the peat layer as compared with the peat-producing plants. The ash elements are distributed unevenly at various depths of the peat horizon. The SiO_2 clearly predominates in the upper part of the profile, while there is more iron in the middle and lower parts. The Ca content is very high throughout the profile, while a small amount of sulfur accumulates in its lower part. These accumulation zones at various depths are of an absolute rather than relative nature, since the total ash content within a layer 1 m thick is approximately the same and very high. This peat soil may be called sulfatic-calcium.

The peat soil is enriched by all ash elements:

	Gray ash	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5	CaO	MgO	SO_3
				in % of dry mass				
Carex gracilis — 40% Phragmites communis — 60%	6.15	2.01	0.27	0.02	0.05	0.48	0.30	0.38
Peat (0—30% cm)	22.55	7.25	0.64	1.11	0.14	7.16	1.03	1.87

---

[3] The water was taken for analysis from all the peatbeds during the same period (June 1958 and 1959).

The ratio of the composition of the peat soil to the composition of the peat-producers gives an idea of the relative accumulation of ash substances:

$$\begin{array}{ccccccc} Al_2O_3 & CaO & SO_3 & SiO_2 & MgO & P_2O_5 & Fe_2O_3 \\ 55.5 > & 14.91 > & 4.92 > & 3.60 > & 3.43 > & 2.80 > & 2.37 \end{array}$$

The greatest differences in the ash composition of peat soil and peat-producers are in the Al content. The amount of the latter in the soil is more than 50 times higher than its content in peat-producers. However, its amount in the 30 cm layer is not even 1%, while the amount of sulfur is 2% and that of calcium 7%.

The considerable enrichment of the profile with sulfur and calcium is due to their addition, since the amount of these substances in ground waters is extremely high, reaching 180 mg/liter of calcium and 300 mg/liter of sulfur. The concentration of organic substances is very small and amounts to 7 mg/liter by C (Table 2).

The deciding factor in the considerable accumulation of ash substances in lowland peat soils is apparently their addition.

Forms of Iron and Calcium Accumulation

Even though the literature contains some information (4, 6, 7, 10) on the quantitative aspect of the accumulation and migration of substances in peat soils, there is little experimental data on the forms of accumulation and migration. In our work we made an attempt at determining the forms of Ca and Fe accumulation. These data are given in Table 3.

In both maritime and continental upland and transitional peat soils all the Ca occurs in the form of exchangeable ions. Such form of Ca also predominates in neutral lowland peatbed with a high ash content. A part of Ca in the maritime peat soil accumulates in the form of gypsum, and apparently carbonate. An insignificant amount of Ca in the form of gypsum also accumulates in the lower part of the profile of the lowland peat soil from the Luga rayon.

The forms of iron accumulation are considerably more varied and complicated. In all the peat soils investigated by us, a large part of the iron forms organo-mineral compounds. The only exception is the lowland peat soil

Table 3

Form of Ca and Fe accumulation in peat soils, % per 100 g of peat

Peat soil	Depth, cm	Ca			Fe_2O_3			
		Total	Free oxides (by difference)[a]	Gypsum	Total	Organo-mineral[b]	Free oxides (by difference)[a]	Free oxides (by difference)
Upland	0—20	0,20	0,20	None	0,17	0,13	0,04	None
	60—80	0,13	0,13	"	0,08	0,07	0,01	"
	170—200	0,21	0,21	"	0,24	0,22	0,02	"
Transitional	0—10	0,27	0,27	"	0,67	0,60	0,07	"
	40—50	0,68	0,68	"	1,47	1,12	0,07	"
Transitional maritime	0—10	0,18	0,18	"	1,50	1,30	0,20	"
	35—45	0,27	0,27	"	3,37	3,23	0,14	"
Lowland	0—5	3,30	3,08	Not det'd	7,19	3,17	None	4,02
	5—15	2,10	1,98	"	39,30	7,88	"	31,42
	15—25	2,36	2,36	"	20,71	12,45	"	8,26
	80—90	4,38	4,03	0,04	3,55	2,96	"	0,59
Lowland maritime	0—10	5,95	3,75	0,01	0,80	0,78	"	0,02
	30—40	5,48	3,41	0,02	1,98	1,72	"	0,08
	80—90	4,47	3,97	0,49	2,02	1,61	"	0,41

[a] The determinations were made after the repeated saturation of peat with a 0.5 N KCl solution.

[b] Extracted by repeated boiling of peat with a 0.1μ solution of $Na_4P_2O_7$ until the separation of organic matter ceased. Determined by the method of Aleksandrova (2).

Note: Comma represents decimal point.

with a huge amount of iron. The entire organic part in the profile of the latter is apparently saturated with iron and the latter also accumulates in the form of hydroxide.

A small part of the iron in the acid upland and transitional peat soils is in the ionic form.

The forms of iron migration in acid transitional and upland peat soils are complicated and varied. These forms include:

a. Ionic (Fe^{++} and Fe^{+++}), taking place in the transitional maritime peatbed, where the possibility of the existence of complex compounds of iron with organic matter is precluded by the very high acidity of soil waters (Table 2).

b. In the form of iron oxide sulfate with the simultaneous movement of large amounts of other sulfates. This form is very likely in the transitional maritime peatbed studied by us (Table 2).

c. In the form of ferrous sulfide. This occurs in maritime peatbed where there is almost always a lot of hydrogen sulfide.

d. In the form of complex organic iron compounds when the reaction of the solutions is less acid, there is a considerable amount of migrating organic matter and a comparatively low amount of migrating iron. This form of movement takes place in the transitional continental peatbed studied by us.

Conclusions

As a result of the development of bog soils, during the transformation of peat-producing plants into peat, some ash elements accumulate and others are being removed so that considerable changes in ash content and composition take place.

In upland peat soils, where peat-producers and the peat itself are fed only by atmospheric waters, the humification and mineralization of the organic mass are very slow, and there is no enrichment of the peat with ash elements. When the peat and the soil waters are acid, the ash elements become mobile and are partially absorbed by plants and are partially removed from the profile of the peat soil. There is an absolute impoverishment of the peat in all the ash substances, and only Fe and Al accumulate relatively in the form of complicated organomineral compounds.

There is a certain periodism in the nourishment of peat-producers by atmospheric and soft soil waters in transitional peat soils. Ash substances are also removed from the profile here under acid conditions. There is no absolute impoverishment of peat because of the considerable accumulation of Fe and Al in the form of organo-mineral compounds in it.

The peat-producers in the transitional maritime soil are fed by waters rich in mineral substances. The increase in the ash content of peat in the profile of these peatbeds results, first of all, from the accumulation of Fe and Al and their concentration in the form of organo-mineral compounds and also sulfur. A considerable part of these substances is brought into the already formed peat from the outside by ground waters.

There is a considerable removal of organic substances from acid, upland, and transitional peat soils, which amounts to 100-120 mg C per liter in bog waters. The migration of calcium and sulfur apparently occurs in the ionic form (Ca^{++} and SO_4^{--}). The migration of iron occurs both in the ionic (Fe^{++} and Fe^{+++}) form as well as in the form of complex organo-mineral compounds, iron sulfates, and ferrous sulfide (the last two forms are characteristic for the peat soils of maritime regions).

Continental and maritime lowland peat soils are fed by neutral waters rich in calcium. As a result of the intense humification and mineralization of peat-producers and, even to a greater extent, because of the introduction of a number of elements by hard waters, the peatbed is enriched with all the mineral substances. The accumulation of iron is especially great in peat soils, and of sulfur in the maritime soils. There is no removal of organic matter in these peatbeds, because of the high Ca content in the water.

Received July 25, 1960

BIBLIOGRAPHY

1. ALEKSANDROVA, L.N. 1949. Method of ash analysis during soil investigations. Pochv. in-t Akad. Nauk SSSR. Sb. 15. Izd. Akad. Nauk SSSR.

2. ALEKSANDROVA, L.N. 1960. Use of sodium pyrophosphate for extracting free humic substances and their organo-mineral compounds from the soil. Pochvovedeniye, No. 2.

3. VERIGINIA, K.V., A.A. ZAVALISHIN, and G.P. MAKSIMYUK. 1940. First results of studied on the water-logging of soils. Sb. Probl. sov. pochvovedeniya. Vol. 11. Izd. Akad. Nauk SSSR.

4. VERIGINIA, K.V. 1950. Problem of the processes of iron migration and accumulation during soil formation. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 34. Izd. Akad. Nauk SSSR.

5. DOKTUROVSKIY, V.S. 1935. Peat bogs. Moscow.

6. NIKONOV, M.N. 1955. Origin and composition of ash in the peat of the forest zone. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 26.

7. NIKONOV, M.N. 1955. Origin of ash in peat. Dokl. Akad. Nauk SSSR. 105 (2).

8. P'YAVCHENKO, N.I. 1960. Biological cycle of nitrogen and ash elements in bog forests. Pochvovedeniye, No. 6.

9. P'YAVCHENKO, N. I. 1960. Nitrogen and ash element cycle in the main types of bog forests. Lectures given by Soviet soil scientists at the VII International Congress in the U. S. Izd. Akad. Nauk SSSR.

10. ROZHNOVA, T. A. and L. S. SCHASTNAYA. 1959. Study of the interrelationship between vegetation and soils under conditions of the isthmus of Karelia. Pochvovedeniye, No. 1.

11. SKRYNNIKOVA, I. N. 1955. Soil processes in cultivated peat-bog soils. Pochvovedeniye, No. 1.

12. SUKACHEV, V. N. 1926. Bogs, their formation, development, and properties. Sel'khozgiz.

13. TANFIL'YEV, G. I. 1889. Bogs of the Petersburg Government. Tr. imp. vol'nogo ekonom. obshchestva. Vol. 2. St. Petersburg.

14. TYUREMNOV, S. N. 1949. Peat deposits and their exploration. Moscow-Leningrad.

15. YAKOVLEV, S. A. 1925. Deposits and relief of Leningrad and its vicinity. Pt. 1. Leningrad.

SOIL-FORMATION PROCESSES DURING THE INVASION OF SANDS BY PLANTS IN THE NORTHERN DESERTS OF THE CASPIAN REGION

T. F. YAKUBOV and R. YE. BESPALOVA, V. V. Dokuchayev Soil Institute of the Academy of Sciences of the USSR

The study of soil-formation processes during the natural invasion of bare moving sands by plants is of great importance in solving the problems of the rational reclamation of deserts and of the increase of their productivity. Improperly utilized (overgrazing, improper plowing, etc.) sandy soils are easily destroyed and become bare moving sands in which, as mentioned by Neustruyev (7), geological processes predominate over soil processes. Soil-formation processes taking place as a result of the natural invasion of bare moving sands by plants have been studied little, and the literature on this problem is very scant. Certain papers are of a very general nature (2, 7), others are primarily devoted to the role of woody-brush vegetation in these processes (4, 5, 6, 13), and only a few papers touch on the problems of soil formation during the natural invasion of sands by grass vegetation (9, 10, 12, 15).

The present paper describes certain data on the influence of the natural invasion of sands by plants on soil formation on the basis of the material collected in 1954 in the Khosheutov sands, located in the western part of the North Caucasian deserts. The climate of the area is dry and continental (14, 15). Air temperature in summer reaches 45°C, while at the soil surface it is 75°C and more. The minimum air temperature in winter is -40°C. Winds play a great role in soil formation. The number of calm days is not more than 10%-15%. The annual precipitation amount does not exceed 200 mm. Evaporation is more than six times higher than precipitation.

The relief in the region of the Khozhukhov sands is undulating-flat. The low, gentle ridges are located at a considerable distance from each other (up to 1 km and more). Well-defined Baer hillock ridges appear with the proximity to the Volga-Akhtuba flood plain. The ridges are occupied by massifs of ridge-barchan and ridge-hillock sands of various dimensions, which are best developed in an easterly direction. A characteristic element of the landscape are shor-solonchaks, found in relief depressions.

Ground waters are found at a depth of 5-6 m in depressions; they are usually mineralized (magnesium and sodium chlorides with a solid residue of 20-40 m/liter). Fresh waters (of the bicarbonate type) accumulate primarily in hollows in bare sands or sands slightly invaded by plants at a depth of 1.5-2 m.

The zonal vegetation is represented primarily by an ephemeral white wormwood association, in which siberian wheatgrass, meadowgrass, wild onion, kochia, Ceratocarpus arenarius, and others participate as well as mosses (Tortula, Bryum) and lichens (Parmelia), which cover the soil to a considerable degree.

Brown sand and sandy loam solonetzic soils predominate, which developed on sand deposits underlain at a depth of 3-5 m by gypsum-bearing clays of a brown or chocolate-brown color with thin interlayers of gravelly gray sand. These soils are not saline. Their humus content does not exceed 1% and gradually decreases with depth.

The nature of soil changes at various stages of invasion by plants were studied along a profile extending more than 1 km and passing through a low ridge on which brown sandy soils were developed in the past. Bare, moving sands formed there as a result of usage of these soils and strong scouring of the vegetation, which later, when the Khosheutov sand-stabilization area (1908) was organized, were under protection until 1918-1919, and became more or less invaded by plants and then used for limited grazing.

At the present time the sands are in various stages of being naturally invaded by plants and only in places, primarily in the central part of the massif, there are areas with bare moving sands.

Several areas in various stages of being invaded by plants and in various stages of soil development were selected along the profile according to the nature of the relief and vegetation.

1) Large, medium-hillock, bare sands 5-10 m high, with only individual Elemus giganteus Vahl in places.

2) Medium-hillock sands 3-5 m high in the stage of invasion by sandy wheatgrass-wormwood (30%-40% coverage), predominantly sand wormwood, siberian wheatgrass, with an

admixture of wild rye, sandy everlasting flower, alyssum, white wormwood, and others. Up to 5-6 cntr of hay, consisting mostly of sandy wormwood can be obtained here form 1 hectare.

3) Low-hillock sands, 1-1.5 m high. These sands are in the stage of invasion by ephemeral white wormwood-wheatgrass and ephemeral white wormwood. They are covered 40%-50% by meadowgrass, siberian wheatgrass, white wormwood, with sandy wormwood, Ceratocarpus arenarius, and an admixture of oriental wormwood. The hay yield is 5-5.5 cntr/ha.

4) Undulating sandy plain with ephemeral white wormwood in which, along with the predominant white wormwood and meadowgrass, individual plants of oriental wormwood, kochia, alyssum and others are found. The soil surface is covered 60%-70% by mosses (Tortula, Bryum) and lichens (Parmelia). The hay yield does not exceed 3 cntr/ha.

Soil profiles and trenches, as well as borings to determine the depth and quality of ground waters were made in each of these areas, representing a definite stage of plant invasion. Moreover, we determined the bulk density of the soil and its moisture throughout the soil profile. For the sake of brevity we will describe the characteristics of the main profiles and present data on the particle-size and chemical composition of the soils studied, as well as the results of determinations of certain of their water-physical properties.

Profile 1. It was taken on a flat, bare summit of a hillock with thin, individual clumps of wild rye.

0-140 cm. Yellowish-brown, fine-grained, friable layer of sand at a depth from 0-11 cm, dry to a depth of 4 cm, and damp from 4-11 cm. The layer from 11-60 cm is damp, slightly compact, forming blocks on drying which are easily destroyed under pressure. Single roots are found from a depth of 20 cm; from a depth of 60 cm the sand becomes dampish-moist and friable.

140-152 cm. Whitish-light-brown, fine pores, sandy loam which becomes whitish on drying. Compact as a result of cementation by salts and forms blocks when excavated.

The sand contains small fragments of broken shells to a depth of 140 cm. The shells are found in places in the form of very thin (fraction of a millimeter), discontinuous interlayers. The sand effervesces weakly from HCl to a depth of 140 cm, and violently below.

Profile 6. Taken in medium-hillock sands at the flat surface of a leveled hillock. The vegetation consists of sand wormwood and siberian wheatgrass with single admixtures of white wormwood, meadow-grass, alyssum and oriental wormwood. The soil surface is covered 30%-40% by the plants.

0-10 cm. Yellowish-brown, friable, fine-grained sand with semi-decomposed and non-decomposed plant residues, giving the sand a grayish tinge.

10-150 cm. Yellowish-brown, fine-grained sand with occasional roots; it is friable from 10-60 cm and slightly compact from 60-150 cm.

Small shell fragments are found throughout the profile. The soil is dry to a depth of 5 cm and is dampish-moist below. Effervesces weakly from HCl throughout the entire depth of the profile.

Profile 9. Taken in low-hillock sands on the flat surface of a strongly leveled hillock. Siberian wheatgrass and white wormwood predominate with a strong admixture of meadow grass, and Ceratocarpus arenarius, and single plants of oriental wormwood and kochia. The woil surface is covered 40%-50% by grasses and about 40% by mosses (Tortula, Bryum).

0-20 cm. Yellowish-brown, fine-grained, silty, friable sand with a grayish tinge and semi-decomposed and non-decomposed organic residues. The layer from 0-5 cm is riddled by very fine rootlets; the grayish tinge and the siltiness are more pronounced than in the 5-20 cm layer.

20-55 cm. Yellowish-brown, slightly compact, moist, fine-grained sand with occasional roots; whitish salt tongues are found in places.

55-140 cm. Yellowish-brown, damp, slightly compact, fine-grained sand. Contains single plant roots.

140-150 cm. Grayish-brown, dry, compact, lumpy sandy loam.

The sandy loam found at a depth of 140 cm apparently represents buried soil. The soil effervesces weakly from hydrochloric acid to a depth of 140 cm and does not effervesce below.

Profile 13. Taken in the plain in a slightly depressed level area. The vegetation consists of white wormwood and meadow grass with Ceratocarpus arenarius, kochia, and oriental wormwood. The soil is covered 50%-60% by grasses and about 70% by mosses (Tortula, Bryum).

0-15 cm. Grayish-light brown, silty, fine-grained sand, slightly compact and riddled with roots; dry from 0-5 cm and damp from 5-25 cm. Effervesces weakly from HCl.

15-86 cm. Brown, silty, fine-grained damp sand, slightly and moderately compact, damp to a depth of 25 cm and dampish-moist below. Does not effervesce.

86-117 cm. Whitish-brown, compact, lumpy, dry sandy loam with fine pores. Plant roots are found occasionally. Effervesces violently from HCl.

117-150 cm. Yellowish-light brown, fine-grained, slightly compact, damp, cohesive sand. Effervesces more weakly than the preceding horizon.

Table 1 gives data on the depth and quality of ground waters in basins and depressions.

We see from the descriptions of the soil profiles that:

Table 1

Composition of ground water

Profile number and soil	Depth of ground water, m	Solid residue, g/liter	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	$Na^+ + K^+$ by difference
1 Primary state of formation	1,6	0,9	$\frac{0{,}543^*}{8{,}9}$	$\frac{0{,}061}{1{,}7}$	$\frac{0{,}136}{2{,}8}$	$\frac{0{,}007}{0{,}4}$	$\frac{0{,}007}{0{,}6}$	$\frac{0{,}288}{12{,}5}$
5 Brown, friable sand	2,1	1,3	$\frac{0{,}586}{9{,}6}$	$\frac{0{,}064}{1{,}8}$	$\frac{0{,}500}{10{,}4}$	$\frac{0{,}022}{1{,}1}$	$\frac{0{,}016}{1{,}3}$	$\frac{0{,}447}{19{,}4}$
9 Brown, cohesive sand	6,0	41,8	$\frac{0{,}154}{2{,}5}$	$\frac{21{,}406}{603{,}0}$	$\frac{3{,}688}{77{,}1}$	$\frac{0{,}899}{44{,}9}$	$\frac{2{,}078}{173{,}2}$	$\frac{10{,}683}{464{,}5}$
13 Brown silty-sand	6,0	38,7	$\frac{0{,}159}{2{,}6}$	$\frac{22{,}684}{639{,}0}$	$\frac{2{,}796}{60{,}3}$	$\frac{1{,}254}{62{,}7}$	$\frac{2{,}327}{193{,}9}$	$\frac{10{,}242}{445{,}3}$

---

*In grams in the numerator and in meq/liter in the denominator

NOTE: Comma represents decimal point.

1. The profile is homogeneous in the large, medium-hillock sands, bare of vegetation (Profile 1). Only the underlying carbonated sandy loam (CO_2, 3.4%), which apparently represents the carbonate horizon of the former weathered soil, now overblown by sand, stands out in color and moisture conditions. Soil formation is in its primary stage and outwardly almost unnoticeable.

2. Soil-formation processes are more noticeable in the medium-hillock sands (Profile 6) which begin to be invaded by plants, especially in the upper (0-10 cm) horizon. There is also a certain redistribution of salts, which is outwardly expressed in the compactness of the sand which increases with depth.

3. Soil-formation processes are more pronounced in the low-hillock sand invaded by vegetation (Profile 9) than in the foregoing profile. This is evidenced by the more intense coloration of humus in the upper horizon of the soil, the larger amount of fines (silt) in it, the presence in the soil profile of whitish tongues, and its compactness.

4. Profile 13 is characteristic of brown silty-sandy zonal soils. The upper horizon (0-15 cm) of these soils is slightly compact, has a grayish tinge, and is followed by a more compact brown illuvial horizon which gradually changes into a compact, whitish, carbonate horizon underlain by slightly compact yellowish-brown sandy loam.

As can be seen from Table 1, the ground water is fresh bicarbonated water in large, medium-hillock sands with soils in the primary stage of formation. The ground water in medium-hillock sands with friable sandy soils is slightly saline because of sodium sulfates. The ground water in low-hillock sands with cohesive sandy soils, as well as in sand plains with silty-sandy soils, are bitter-saline (magnesium and sodium chloride type).

Table 2 gives the results of determinations of the particle-size composition of the soils which indicate that, as the sands become invaded by plants and soil formation processes develop, there is a gradual increase of silt and clay particles. It is understandable that the heterochronous nature of the deposits had a certain influence on the particle-size composition of the soils, since eolian processes took place under the influence of variable natural factors. Moreover, weathering and impulverization, as pointed out by Vysotskiy (3), Neustruyev (7), and others, had an influence on the particle-size composition. Tomashevskiy (12) believes that impulverization is of essential importance for soil formation under the foregoing conditions. Unfortunately we do not yet have sufficient actual data in order to evaluate this phenomenon, even though it is important to take it into account.

On the basis of the morphological structure of the soils and the results of particle-size analysis we may distinguish the following series (stages) of soil development and formation under the conditions studied and the natural invasion of sands by plants: soils in the primary stage of

Table 2

Particle-size composition (according to the method of Kachinskiy), %

Depth, mm	Loss on treatment with HCl	Particle diameter, mm						
		1,0—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	< 0,001	<0,01
Profile 1								
0—10	2,6	0,1	91,8	0,2	0,2	0,2	4,9	5,3
10—20	2,2	0,1	91,6	0,1	0,3	0,6	5,1	6,0
20—30	2,1	none	91,7	0,1	0,1	0,2	5,8	6,1
40—50	2,2	0,2	92,1	0,1	0,1	0,3	5,0	5,4
60—70	1,9	0,3	92,5	0,3	0,2	0,2	4,6	5,0
90—100	2,2	0,4	90,5	0,2	0,8	0,8	5,1	6,7
120—130	2,5	0,2	90,3	0,8	0,1	0,7	5,4	6,2
140—150	12,8	none	60,0	7,6	2,1	7,2	10,3	19,6
Profile 6								
0—10	1,7	0,2	91,2	0,7	0,1	0,7	5,4	6,2
10—20	1,8	0,1	92,0	0,5	0,2	0,2	5,2	5,6
20—30	1,6	0,2	92,1	0,2	0,2	0,9	4,8	5,8
40—50	1,8	0,2	92,0	0,2	0,2	0,8	4,8	5,8
60—70	1,6	0,1	91,5	0,4	0,4	0,6	5,4	6,4
90—100	1,7	0,2	91,6	0,3	0,6	0,7	4,9	6,2
120—130	1,8	0,1	91,4	0,3	0,4	0,6	5,4	6,4
140—150	1,6	0,3	91,6	0,3	0,6	0,4	5,2	6,2
Profile 9								
0—5	0,8	0,1	87,8	3,1	0,4	1,2	6,6	8,2
5—10	0,9	0,1	90,3	1,3	0,5	1,1	5,8	7,4
10—20	0,7	0,1	92,4	0,5	0,7	0,4	5,2	6,3
20—30	0,8	0,5	91,7	0,7	0,4	0,1	5,8	6,3
40—50	0,7	0,1	92,2	0,5	0,3	0,6	5,6	6,5
60—70	0,8	0,1	91,7	0,8	0,7	0,3	5,6	6,6
90—100	0,8	0,1	92,0	0,7	0,3	1,7	4,4	6,4
120—130	0,6	0,1	89,7	2,3	0,1	1,2	6,0	7,3
Profile 13								
0—5	0,9	0,2	82,2	7,3	0,9	1,9	6,6	9,4
5—15	0,7	0,2	82,5	8,4	0,4	1,8	6,0	8,2
15—25	0,9	0,3	87,1	4,8	0,8	1,8	4,3	6,9
25—35	0,9	0,2	86,3	3,3	1,2	1,1	7,0	9,3
35—45	0,5	0,4	83,4	4,8	0,6	1,8	8,5	10,9
45—55	0,6	0,2	84,7	4,1	0,4	1,6	8,4	10,4
90—100	0,6	0,2	65,2	17,4	1,8	2,9	11,9	16,6
120—130	0,5	0,4	89,3	2,5	0,1	0,9	6,3	7,3

NOTE: Comma represents decimal point.

formation → brown, friable sandy soils → brown cohesive sandy soils, changing further into brown, silty-sandy zonal soils.

The process of soil formation takes place in a weakly alkaline medium. Alkali earths predominate among cations and bicarbonates among anions. As the sands are being invaded and soil-formation processes develop in them they become very slowly and weakly salinized.

The content of CO_2 carbonates does not exceed 0.4% in any of the profiles and changes little along the profile. An exception are silty-sandy soils (Profile 13), which contain about 4% CO_2 at a depth of 0.9-1 m.

The amount of humus is also small, not exceeding 0.4% and decreasing with depth. The insignificant increase in humus found at a depth from 0.5-1 m may be the result not only of the decomposition of plant residues, but also of their addition from the outside during deflation.

In general, when the sands are being invaded by plants and soil-formation processes develop in them, the amount of humus gradually increases, nearing its content in brown silty-sandy zonal soils, a fact that was also noted by Popazov (10).

Table 3

Certain analytical data for the soils studied

Profile No.	Depth, cm	CO_2 (det'd acrd to Geysler-Maksimyuk), %	Humus (det'd acrd to Tyurin), %	Adsorption capacity, meq	Exchangeable Na^+, meq [a]	K_s coef of the ° of solonetz det'd by the filtr. method[b]
1	0—10	0,3	0,03	1,96	0,4	2,7
	10—20	0,3	0,02	1,92	0,4	1,5
	20—30	0,3	0,02	2,06	0,5	1,0
	40—50	0,1	none	2,19	0,4	2,0
	60—70	0,2	same	1,90	0,4	1,0
	90—100	0,2	0,02	2,01	0,4	not det'd
	120—130	0,3	not det'd	2,11	0,4	same
6	0—10	0,3	0,13	2,14	0,4	5,5
	10—20	0,2	0,05	2,23	0,4	1,2
	20—30	0,2	0,08	2,28	0,4	1,6
	40—50	0,2	0,09	2,00	0,4	1,3
	60—70	0,3	0,09	2,09	0,4	2,1
	90—100	0,3	0,07	2,35	0,4	1,0
	120—130	0,3	not det'd	2,35	0,4	not det'd
9	0—5	0,3	0,22	2,69	0,4	1,1
	5—10	0,9	0,10	2,98	0,4	4,2
	10—20	0,3	0,11	2,81	not det'd	not det'd
	20—30	0,2	0,09	2,47	0,4	3,4
	40—50	0,2	0,07	2,69	0,4	3,4
	60—70	0,4	0,04	2,31	not det'd	not det'd
	90—100	0,2	0,12	3,49	0,4	1,0
	120—130	0,1	not det'd	3,25	0,4	2,4
13	0—5	0,3	0,41	3,73	0,4	3,0
	5—15	0,2	0,27	3,42	0,4	3,5
	15—25	none	0,22	3,58	0,4	<1,0
	25—35	same	0,27	4,27	0,4	not det'd
	35—45	"	0,33	5,16	0,4	~1
	45—55	"	0,33	5,52	0,4	<1,0
	90—100	3,8	0,46	4,87	0,7	<1,0
	120—130	1,5	not det'd	3,01	1,1	2,5

---

[a] The exchangeable sodium was determined by the method of Gedroyts by substituting with calcium of calcium carbonate (analyzed by Ye. A. Chakvetadze). The adsorption capacity was determined in the laboratory of soil investigations at the Chair of Soil Science of the Timiryazev Academy of Agriculture.

[b] The filtration analysis was made by Ye. A. Chakvetadze according to the method described by I. N. Antipov-Karatayev and A. A. Zeytsev (1).

The adsorption capacity of the soils studied (Table 3) is very low because of their insignificant adsorption complex. As the sands are being invaded by plants and the content of fines and organic matter increases, the adsorption capacity also increases, though very slowly. This is noticeable, for instance, when we compare the data for Profile 1 (bare sands) with those for Profile 9 (cohesive sandy soils). The adsorption capacity of the latter profile s close to that of Profile 13, represented by silty-sandy soils only slightly affected by deflation.

Some investigators point out that under the foregoing conditions not only the adsorption capacity increases, but zonal properties develop, such as solonetization, even accompanied by the formation of a solonetz horizon (9, 10). However, we found no signs of solonetzation either morphological or from data on water extracts, in the sandy soils studied by us, which have a very small adsorption complex. This feature of sandy soils was mentioned in his time by Polynov (8). Nevertheless, a direct determination of exchangeable sodium indicates that even though the absolute amount of exchangeable

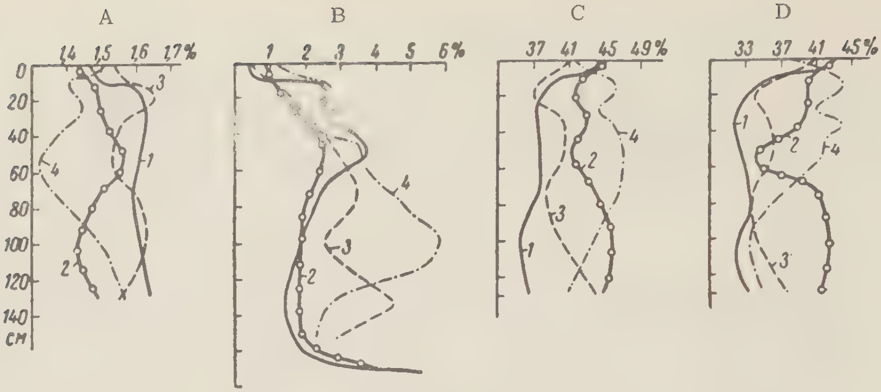

Fig. 1.- Certain water-physical data on the soils studied.
a - bulk density; B - moisture; C - porosity; D - aeration.
1 - Profile 1; 2 - Profile 9; 3 - Profile 6; f - Profile 13.

sodium is insignificant (not more than 0.02% or 0.4-0.5 meq/100 g of soil) its content is 20%-25% of the total adsorption capacity. The fact that analyses disclosed a relatively high amount of sodium in the adsorption complex of even granular, moving sands, where no other index showed the presence of solonetzation, indicates that the determination of the solonetzation of sands and sandy soils by direct determinations of adsorbed sodium, in particular by the methods used, is doubtful. Consequently, the classification of the degree of solonetzation, worked out for finely textured soils, is apparently also inapplicable to sands and sandy soils having an insignificantly small adsorption complex. The method of determining adsorbed sodium as well as the classification of the degree of solonetzation from the content of exchangeable sodium apparently requires improvement for sands and sandy soils.

In addition to differences in particle-size and chemical composition, each stage of soil formation in sands is characterized by definite water-physical properties.

If we examine Table 4 and Figure 1, we will see that the surface layer (0-10 cm) in all profiles is the driest in summer. The moisture content of this layer is lowest in bare sands (0.4%), which is attributable not only to evaporation, but also by the blowing over of dry sand from the side.

There is a noticeable increase in moisture content at a depth from 10-50 cm in bare sands, which reaches a maximum, approximately equal to the ultimate field moisture capacity (about 2.5%) in the bare sands of Profile 1. This agrees with the data of Tomashevskiy (11, 12) for the same sands.

The moisture content of friable sandy (Profile 6) and cohesive sandy (Profile 9) soils at a depth from 10-50 cm is somewhat lower than in bare sands (Profile 1) because of transpiration. The drying effect of vegetation at the foregoing depth is also observed in silty-sandy soils (Profile 13).

The behavior of moisture in the deeper layers of the foregoing soils is the following: in Profile 1 and 9 the moisture content gradually decreases from a depth of 50-60 cm to a depth of 1.4-1.5 m, and sharply increases below as a result of the infiltration of water from showers which took place a month before our investigations. The precipitation was retained in Profile 6 and two layers with an increased moisture content formed at a depth from 60-70 cm and from 120-130 cm. As far as Profile 13 is concerned, its moisture content increases with depth and reaches a maximum (5%-8%) at a depth of about 0.9-1 m and then decreases down to the capillary fringe of ground waters (4-4.2 m). The peculiarities of the moisture conditions in each of the soils studied can be seen in Figure 2.

The data show that there are certain differences in the nature of soil moisture during various stages of soil formation. As the sands become invaded by plants, the moisture content of the soil decreases gradually, especially in the root zone, as a result of the transpiration and the development of soil-formation processes. This confirms the statement by Vysotskiy (3) that as sands become invaded by plants they "lose moisture and become drier."

The results of bulk density determinations (Table 4) show that in all the varieties of sandy soils the bulk density is less in the surface horizon (0-10 cm) than in the lower-lying horizons. The only exception are silty-sandy soils (Profile 13) with a slightly compacted surface horizon.

The bulk density of soil in bare, moving sands (Profile 1) is almost the same in the entire soil layer, except for the upper layer (0-10 cm), and in the parent material. The bulk density curve for friable sandy soils (Profile 6) is close to that for bare sands (Profile 1). The bulk density of cohesive sandy soils is intermediate between that of bare sands and silty-sandy soils (Profile 13). The bulk density of these soils increases somewhat at a depth from 10-60 cm, reaches a maximum in the layer from 40-50 cm, and then decreases to increase again in the parent material. In zonal silty-sandy soils (Profile 13) the bulk density decreases to a

Table 4

Results of determinations of the water-physical properties of the soils

Depth, cm	Profile No.	Specific gravity, (d)	Bulk density[a] (P), g/cm³	Moisture[a] (W), %	Total porosity $v = \frac{d-p}{d}\cdot 100$	Aeration $a = v - P\cdot W$, %
1	0—10	2,61	1,47	0,41	43,7	43,1
	10—20	2,61	1,61	2,82	38,3	33,8
	20—30	2,57	1,63	2,64	36,7	32,4
	40—50	2,60	1,62	3,69	37,7	31,7
	60—70	2,57	1,59	2,53	38,1	34,1
	90—100	2,50	1,62	1,90	35,2	32,0
	120—130	2,59	1,64	1,43	36,7	34,4
6	0—10	2,63	1,54	0,54	41,4	40,6
	10—20	2,60	1,65	1,36	36,5	34,3
	20—30	2,60	1,57	2,03	39,6	36,4
	40—50	2,57	1,53	2,91	40,4	35,9
	60—70	2,61	1,60	3,48	38,7	34,1
	90—100	2,66	1,62	2,46	40,0	35,0
	120—130	2,77	1,54	4,41	44,4	37,6
9	0—5	2,61	1,44	0,87	44,8	43,5
	5—10	2,58	1,50	1,16	41,8	40,1
	10—20	2,58	1,50	1,36	41,8	39,8
	20—30	2,62	1,49	1,85	43,1	40,3
	40—50	2,64	1,57	2,58	40,5	35,4
	60—70	2,67	1,49	2,23	44,2	41,0
	90—100	2,66	1,43	1,93	46,2	43,4
	120—130	2,68	1,48	1,83	44,8	42,1
13	0—5	2,57	1,50	1,20	41,8	39,0
	5—15	2,65	1,40	2,32	47,2	44,0
	15—25	2,56	1,44	2,14	43,8	40,7
	25—35	2,60	1,39	2,05	46,5	43,7
	35—45	2,56	1,36	3,72	46,9	41,8
	45—55	2,49	1,32	3,59	47,0	42,3
	90—100	2,62	1,50	5,79	42,7	34,0
	120—130	2,63	1,56	2,85	40,7	36,3

[a] Moisture and bulk density were determined three times on July 16, 1954.

NOTE: Comma represents decimal point.

depth of about 50-60 cm, and then gradually increases to reach a maximum at the bottom of the profile.

Thus, during various stages of the invasion of sands by plants and of the development of soil-formation processes, the bulk density of the root zone is lower than that of the layer from 0.5-1 m, where it increases as a result of the increased content of clay particles.

The calculated porosity and aeration values of the foregoing soils are the reverse of bulk density values, as we can see from Figure 1.

Conclusions

1. The following series (or stages) of soil development and formation take place in the sands studied by us during their invasion by plants: soils in the primary stage of formation → brown, friable sandy soils → brown, cohesive sandy soils, changing into brown silty-sandy zonal soils.

2. Each of the foregoing stages of soil development is characterized by definite morphological features, reflecting the intensity of soil-formation processes.

As the sands become invaded by plants the content of fines in the soils increases, especially that of silt and clay particles, the humus content increases, salinity increases somewhat, and the adsorption capacity increases. As the

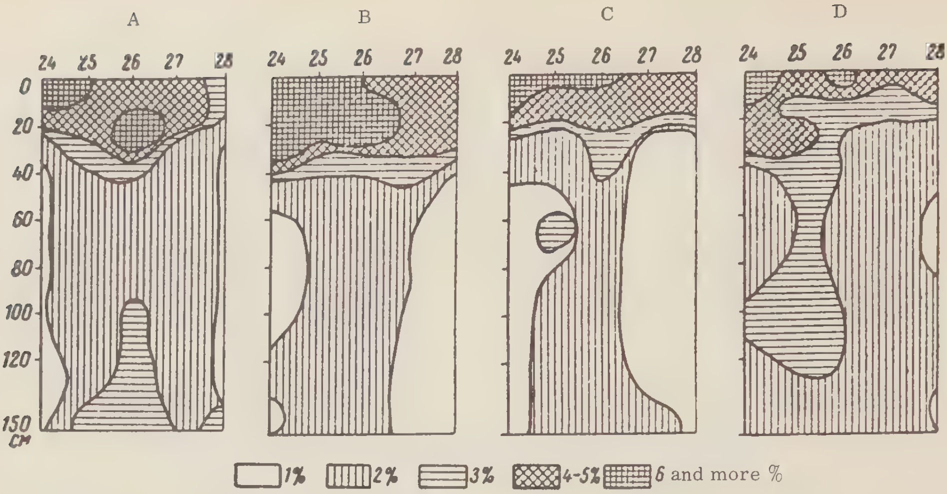

Fig. 2.- Moisture content of sandy soils.
Profiles: A - 1; B - 6; C - 9; D - 13. The numbers 24-28 represent the days when soil moisture was determined; the determinations were repeated 3 times.
Precipitation was: 8.9 mm on July 22; 6.8 mm on July 23, and 1.6 mm on July 25.

sands become invaded and soil-formation processes develop, their water-physical properties also change.

Sands in various stages of natural invasion and soil formation are characterized by a varying productivity, which is generally low, both qualitatively and quantitatively. The productivity of sandy lands and the quality of the grass stand may be increased considerably if their stage of invasion by plants and soil formation are properly taken into account (15, 16).

BIBLIOGRAPHY

1. ANTIPOV-KARATAYEV, I. N. and A. A. ZAYTSEV. 1946. A complex method of reclaiming solonetzic lands of the chestnut soil zone of the Volga region under irrigation conditions. Problemy sov. pochvev. Sb. 14.
2. VYSOTSKIY, G. N. 1911. Soil-formation processes in sands. Instruction for the investigation of granular sands in Russia. Izv. geogr. ob-va. 47(6).
3. VYSOTSKIY, G. N. 1924. Essays in forestry. Zap. Belorusskogo ges. in-ta s.-kh. No. 3.
4. GAYEL', A. G. 1939. Role of plants in soil formation in the Kara-Kum desert, sandy soils and their fertility. Izv. RGO. 71(8).
5. DUBYANSKIY, V. A. 1928. A sand desert of southeastern Kara-Kum. Tr. In-ta po prikladnoy betan., genetike i selektsii. 19(4).
6. ZONN, S. V. and B. L. LEONT'YEV. 1942. Important of Haloxyion in soil formation on the desert sands of Kara-Kum. Pochvevedeniye. No. 8.
7. NEUSTRUYEV, S. S. 1911. Soil-formation processes in granular sands. Instructions for the investigation of granular sands in Russia. Izv. RGO. 47(6).
8. POLYNOV, B. B. 1933. Processes of soil salinization and desalinization. Tr. Komissii irrigatsii. Vol. 1.
9. POPAZOV, D. I. 1953. Soil-formation process in the southeastern part of the Volga-Urals sand massif. Dokl. TSKHA. No. 17.
10. POPAZOV, D. I. 1954. Certain results of soil investigations in the southeastern part of the Volga-Urals sand massif. Pochvovedeniye. No. 5.
11. TOMASHEVSKIY, I. I. 1921. Hydrological properties of soils and sands in the southern part of Astrakhan' Government. Ekonomicheskaya zhizn'. No. 2.
12. TOMASHEVSKIY, I. I. 1931. Sands of the Astrakhan' steppe. Tr. po lesnomy opytn. delu. Tsentr. lesnaya op. stantsiya. No. 10.
13. YAKUBOV, T. F. 1937. Soil formation in sands under the influence of woody plants. Khmizatsiya sots. zemled. No. 4.
14. YAKUBOV, T. F. 1938. Naryn sands of the semi-desert of the Lower Trans-Volga region. Tr. Pochv. in-ta. Vol. 17.
15. YAKUBOV, T. F. 1955. Sand deserts and semi-deserts of the Northern Caspian region. Izd. Akad. Nauk SSSR.
16. YAKUBOV, T. F. and R. YE. BESPALOVA. 1956. Natural pastures in the sandy areas of the Southeast and their improvement. Zhivotnovodstvo. No. 4.

NITRATE SOLONCHAKS OF THE MURGAB OASIS

V. A. MOLODTSOV, V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR

Nitrate solonchaks are characteristic of the desert-steppe and desert zones of Central Asia. Such solonchaks were studied by various investigators in the ruins of Kunya-Urgench (7, 2, 3), Bukhara (4), Anau (2, 10), and other cities and settlements of Central Asia. In addition, there are descriptions in the literature (1, 7), of nitrate solonchaks on dense parent material, containing organic matter.

There are two points of view on the origin of nitrate solonchaks. Kovda and Selyakov (4, 10) believe that the source of saltpeter in them is ground water rich in nitrates; the accumulation of nitrates is a solonchak process.

Other investigators (5, 8, 1, 2, 3) believe that the nitrates form from organic plant and animal residues under the influence of microbiological activity. This is also accepted by Selyakov in another paper (11), however, the problem is not very clear.

Nitrate solonchaks are widespread in the Murgab oasis. Certain data on the extent of nitrates in them are given in the papers of Selyakov (10) and Dzhumayev and Nosov (3).

We studied the solonchaks in the ruins of the old Merva. This city was destroyed in the 13th century by the Mongols and was never restored. The remains of the city occupy 225 ha (2). The soil of the solonchaks was used in the past as raw material for obtaining saltpeter from which gunpowder was made.

Vegetation is very thin on these solonchaks and primarily represented by Peganum harmala, Alhagi pseudoalhagi, and certain Russian thistles.

Profile 133 was made on a hill at a distance of 300 m south of the mausoleum of Sultan Sandzhar. The surface is littered with fragments of clay and glassware, pieces of brick, and bones. The morphological profile is characterized by the absence of clearly-defined horizons. There is a thin, brittle crust at the surface which is underlain by a poorly-defined salt horizon. The entire profile is slightly compacted, strongly mixed, and contains fragments of brick, ceramics, coal, bones, and other remains of the culture of man. A common characteristic of these solonchaks is that they are sandy loam and fine clay loam, and have a white, mealy inclusion in all horizons, consisting primarily of gypsum.

The amount of water-soluble salts is very high in the solonchak, averaging about 7% in the upper 1.5 m (Table 1). The salts are relatively evenly distributed throughout the soil profile, which distinguishes these solonchaks from other solonchaks in which salts usually concentrate in the layer from 0-20 cm.

The composition of salts in the solonchak is unusual. In addition to a high content of chlorides and sulfates, there is a large amount of nitrates (NO_3), more than 1.5%. According to salt composition this solonchak is nitrate-chloride-sulfate solonchak, but for the sake of brevity we shall call it hence nitrate solonchak.

Because the soil is mixed, humus is distributed unevenly, varying from 1%-2% along the profile to a depth of 1.5 m. In spite of its fine texture it occurs in larger amounts in the nitrate solonchak than in the chloride-sulfate solonchak. The carbonate content in these solonchaks is high, 27%-28% (Table 2). Magnesium carbonate amounts to 3.5%-5.0%, or 15%(20% of the sum of carbonates.

The formation of nitrates as a result of the biogenic decomposition of organic residues is most likely for the following reasons.

1. Nitrate solonchaks are found in the ruins of old cities, settlements, and cemeteries located on elevated relief elements where ground water is found at a depth of 10-20 m and cannot take part in the accumulation of nitrates and other salts. Moisture determinations made in the nitrate solonchak on May 20 (Table 1) showed that it is dry throughout the entire profile. The existing moisture is derived from the large amount of hygroscopic salts.

2. The chloride-sulfate solonchak (Profile 116), located in the flood plain of the Murgab River, in which salts formed as a result of the evaporation of ground water, contains hundreds of times less nitrates than nitrate solonchak (Table 1, and Figure 1), even though the amount of water-soluble salts in its upper horizon is several times higher. This proves that the accumulation of nitrates in nitrate solonchak did not occur as a result of the evaporation of ground water.

Table 1

Analysis of water extracts from soils of the Murgab oasis, % of absolutely dry sample

Depth, cm	Moisture content %	Solid residue	NO_3^-	HCO_3^-	Cl^-	$SO_4^{=}$	Ca^{++}	Mg^{++}	Na^+	K^+	%potassium in sum of cations
Nitrate-chloride-sulfate solonchak. Profile 133											
0—10	3,1	8,250	1,660	0,044	2,141	0,917	0,270	0.032	1,675	0,975	22,1
10—20	8,1	6,920	0,870	0,028	1,225	2,136	0,392	0,038	1,080	0,850	23,0
20—30	10,4	8,970	1,430	0,033	1,490	2,640	0,510	0,038	1,480	1,050	21,6
40—50	9,2	7,220	0,910	0,039	1,354	2,028	0,417	0,050	1,000	0,975	26,9
60—70	7,9	6,365	0,830	0,028	0,877	2,220	0,343	0,044	0,980	0,725	22,6
80—90	10,0	6,150	0,960	0,028	1,103	1,620	0,340	0,047	0,897	0,825	26,4
120—130	9,4	5,826	0,930	0,011	0 774	1,800	0,377	0,059	0,775	0,800	26,1
140—150	12,1	4,926	0,930	0,028	0,875	1,272	0,255	0,085	0,595	0,700	28,5
Chloride-sulfate solonchak. Profile 116											
0—10	not det'd	20,805	0,063	0,058	2,051	11,198	0,270	1,308	3,750	0,195	1,6
10—25	same	3,275	0,025	0,026	0,406	1,623	0,262	0,171	0,360	0,055	3,0
25—50	"	2,725	0,011	0,020	0,290	1,434	0,263	0,118	0,300	0,047	3,0
50—72	"	0,996	0,003	0,015	0,165	0,514	0,030	0,051	0,180	0,021	3,7
72—99	"	0,602	0,001	0,020	0,069	0,370	0,032	0,033	0,082	0,009	2,5
99—112	"	1,156	0,001	0,015	0,097	0,373	0,097	0,068	0,125	0,012	2,0
112—150	"	0,402	0,001	0,020	0,048	0,206	0,024	0,025	0,070	0,004	1,5
150—200	"	0,824	0,008	0,018	0,065	0,461	0,110	0,038	0,080	0,005	1,0
Ash of plants used for fuel											
—	—	13,150		0,314	2,570	3,530	0,044	0,007	1,620	4,820	62,2
Air-dried brick from the wall of the Bayram-Ali fortress											
—	—	4,962	2,270	0,027	0,639	0,231	0,382	0,056	0,545	0,512	12,3
Water from the Murgab River, mg/liter											
—	—	530	1,02	183	72	120	64	22	64	3	1,0

Note. Profile 116 was made by N. G. Minashina. The analyses were conducted by G. I. Mel'nikova, except for the determination of nitrates. The nitrates were determined by the method described in the Doklady Akad. Nauk TadzhSSR, Vol. 1, No. 2, 1958.

NOTE: Comma represents decimal point.

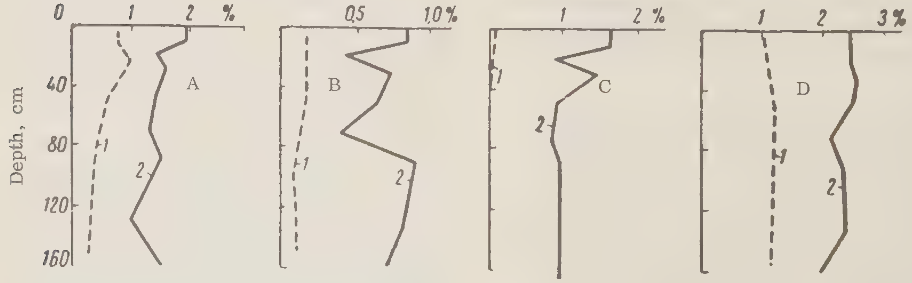

Fig. 1.- Content of humus and nutrients in chloride-sulfate and nitrate solonchaks. A - humus; B - total phosphorus (P_2O_5); C - nitrates (NO_3); D - total potassium (K). Solonchak: 1 - chloride-sulfate; 2 - nitrate.

Table 2

Certain chemical data on the composition of soils

Depth, cm	Carbonates, %			Phosphorus		Potassium		Humus (det'd by Tyurin method)
	$CaCO_3$	$MgCO_3$	% $MgCO_3$ in the sum of carbonates	Total, %	Available del'd by Machigin method, mg/kg	Total, %	Exchangeable (det'd by Protasev method) mg/kg	%
Chloride-sulfate solonchak. Profile 116								
0—10	15,8	4,02	20,2	0,172	26	1,05	2250	0,80
10—25	20,2	5,21	20,5		50		610	1,04
25—50	22,8	5,39	19,1	0,170	38	1,20	515	0,57
50—72	Not determined						260	0,34
72—99	19,4	2,17	10,0	0,120	7	1,20	160	0,23
99—112	Not determined						160	0,20
112—150	19,6	2,02	9,3	0,08	3	1,15	75	0,18
Nitrate-chloride-sulfate solonchak. Profile 133								
0—10	21,6	5,39	20,0	0,857	150	2,45	10200	1,93
10—20	Not determined			0,440	207	2,45	9650	1,40
20—30	19,6	4,02	16,9	0,736	207	2,55	12500	1,60
40—50	Not determined			0,627	165	2,45	11130	1,40
60—70	21,4	4,02	15,8	0,406	250	2,15	8670	1,30
80—90	19,4	3,50	15,2	0,950	235	2,35	10120	1,50
120—130	Not determined			0,795	215	2,35	9500	0,98
140—150	20,2	3,86	15,7	0,695	135	1,95	8200	1,50
Ash of plants used as fuel								
	20,6	9,41	31,7	1,021	250	5,20	Not det'd	1,81
Air-dried brick from the wall of the Bayram-Ali fortress								
	Not determined			0,180	125	1,30	6870	1,10

Note: Comma represents decimal point.

3. The specificity of the salt composition of nitrate solonchak, as compared to chloride-sulfate solonchak, is expressed first of all in the relatively high content of potassium in the nitrate solonchak, which amounts to 10%-20% of the sum of cations, whereas chloride-sulfate solonchak contains 1%-3% (i.e., the same amount as in the irrigation and ground water). This element is contained in large amounts in the products of the life activity of animals and man. Secondly, in the small amount of water-soluble magnesium in nitrate solonchak, as compared to chloride-sulfate solonchak. In the former, magnesium amounts to 2%-10% of the sum of cations, while in the latter it amounts to up to 40%. Consequently, the source of accumulation of magnesium in chloride-sulfate solonchak is ground water, while there is no such source in nitrate solonchak.

4. Chloride-sulfate solonchaks of the Murgab oasis are characterized by a considerably higher amount of water-soluble salts in the upper horizons as compared to the lower horizons. This is much less pronounced in nitrate solonchak. If the lower horizons of chloride-sulfate solonchak contain only about 3% of the salts contained in its upper horizon, in nitrate solonchak they contain 60%. The relatively even distribution of salts in the profile of nitrate solonchak and their high content indicate that the salts accumulating in it are not derived from ground water (in the opposite case they would have been drawn to the surface of the soil).

5. Chloride-sulfate solonchak also differs from nitrate solonchak by the composition and content of carbonates. If in nitrate solonchak the magnesium carbonate content varies from 3.5%-5.3% along the entire profile, in chloride-sulfate solonchak this amount is found only in the upper horizons, where it was derived from ground water, while in its lower horizon the amount of magnesium carbonate is two times smaller; this proves that ground water does not participate in the salt formation in nitrate solonchak. The high content of magnesium carbonates in nitrate solonchak is due to its considerable biological accumulation. Thus, the ash of plants, used by the local population for fuel, contains 9% of magnesium carbonate (Table 2), while the deposits of the Murgab River contain 1.5%-2.5%.

6. Nitrate solonchak differs from chloride-sulfate solonchak in that it contains a considerable amount of humus, and available and total phosphorus and potassium (Fig. 1). The humus in the upper 1.5 m of nitrate solonchak amounts to 285 metric tons/ha, phosphorus amounts to 150 metric tons/ha, while chloride-sulfate solonchak contains respectively 70, 30, and 140 metric tons/ha, i.e., 2.5-5 times less. The amount of phosphorus and potassium (total and

available forms) is especially high in nitrate solonchak, which is an evidence of their biological accumulation. If the accumulation of nitrates from ground water is possible, it is impossible in the case of humus and phosphorus.

It would not be wrong to assume that the salt composition of plant and animal residues is the same as the salt composition of the ash of plants from the same region. The analysis of the ash of these plants (Table 1) showed that it contains 13% of water-soluble salts, whereby their composition is the same as in nitrate solonchak. In addition to water-soluble salts, there is a large amount of phosphorus, potassium, magnesium, and calcium in the ash.

Under conditions of Central Asia the main sources of fuel are camelthorn, tamarisk, Haloxylon, and various thistles. The ash, as well as the products of the life activity of animals and man were not taken out into the fields in the past and even now, but dumped in settlements or in their vicinity. These are the places where the unusual solonchaks, which contain a considerable amount of nitrates and other nutrients, form.

S. N. Selyakov in advancing his theory of the accumulation of nitrates from ground water, does not give the results of their analysis with the exception of one sample which contains not too large an amount of nitrates. The determination of the nitrates in ground and river waters of the Murgab oasis (25 samples) showed that their content is insignificant, and that they are entirely absent in many cases (Table 3). The water of the Murgab River, which is the source of salts and ground water in the Murgab oasis, contains the same amount of nitrates as other rivers of Central Asia. They amount to 0.2%-0.3% of the sum of water-soluble salts as in chloride-sulfate solonchak, while in nitrate solonchak they amount to up to 10%-20%.

The main argument against the biogenic accumulation of nitrates, in the opinion of Selyakov, is the fact that the microorganisms cannot bear such a high concentration of salts as is found in nitrate solonchaks. It is true that such a high concentration of salts can greatly disturb and possibly even put a stop to microbiological activity, even though there are data which indicate that microorganisms can stand high salt concentrations (3, 6, 8). But the high salt concentrations may be the result of a secondary process of salinization. The hills, on which the nitrate solonchaks are located at present, are a sort of "wicks" which draw water-soluble salt from the surrounding areas, including the nitrates which are located lower where conditions are favorable for the development of microorganisms because of higher moisture. The high concentration of salts, the strong drying of nitrate solonchaks in the course of many years, as well as their good aeration which inhibit the denitrification process, cause the accumulation and preservation of the nitrates.

Thus we may conclude that the main source of salts in nitrate solonchaks is the product of the life activity of man and animals, while their accumulation is a secondary phenomenon as a result of the redistribution of salts at the surface.

The results of an analysis of 800-900-year old sun-dried bricks from the Bayram-Ali fortress are clear proof of the microbiological accumulation of nitrates in the Murgab oasis. In the brick taken from a height of 1.5 m above the ground we found 2.2% NO_3 and 1.1% humus. The nitrification rate averages 25 mg NO_3 per year. It must be noted that saltpeter amounted to 60% of the sum of water-soluble salts in this brick, while chlorides amounted to only 15%. The composition and location of the sample indicate that ground water could not have taken part in the accumulation of nitrates.

Table 3

Salt and nitrate content in the ground water of the Murgab oasis, g/liter

Sample No.	Solid residue	NO_3^-	% NO_3 in the sum of salts	Sample No.	Solid residue	NO_3^-	% NO_3 in the sum of salts
1	40,456	None	—	14	9,61	0,008	0,008
2	40,96	Trace	—	15	10,17	0,006	0,06
3	32,04	"	—	16	12,96	0,002	0,015
4	39,02	0,003	0,008	17	20,49	0,002	0,010
5	39,27	Trace	—	18	43,03	0,016	0,040
6	39,52	0,001	0,002	19	42,25	0,004	0,010
7	39,30	0,053	0,13	20	41,98	0,007	0,012
8	42,03	0,002	0,005	21	44,04	0,007	0,011
9	41,64	0,061	0,14	22	3,25	0,003	0,002
10	34,43	0,025	0,070	23	13,56	0,001	0,001
11	38,31	0,002	0,005	24	16,80	Trace	—
12	41,53	0,002	0,005	25	22,61	0,001	0,01
13	42,03	0,002	0,004				

NOTE: Comma represents decimal point.

On the basis of data found in the literature and our own observations we concluded that the accumulation of nitrates in the solonchaks of the Murgab oasis is the result of microbiological activity, and the initial material for this is adobe brick, bones, ash, and other organic remains.

Nitrate solonchaks contain a large amount of nutrients: nitrate nitrogen, phosphorus, potassium, magnesium, and, apparently, microelements. The layer containing a considerable amount of nutrients is 1.5 m and more thick. One metric ton of nitrate solonchak contains 15 kg potassium, 2 kg phosphorus, and 10 kg nitrates in a form available to plants. The total contents of these elements are even higher, amounting to 30 kg of potassium and 7 kg of P_2O_5. Consequently, nitrate solonchaks may be used as fertilizers which contain these elements. To ensure a high yield of cotton it is sufficient to add 8-10 metric tons/ha of this solonchak. The effect of toxic salts will not be felt, since their content in the root zone increases only by 0.002%.

It must be noted that these solonchaks can be used to improve the physical properties of finely-textured soils.

The foregoing process of nitrate accumulation is an individual case of the widespread and characteristic process taking place under desert conditions of Central Asia, which was noted by Rozanov (9), who found nitrates in all takyr soils of Southern Turkmenistan and along their entire profile, often in amounts exceeding the amount of chlorides. In his opinion, the accumulation of nitrates is the result of the active mineralization of organic substances when their requirement by higher vegetation, which is almost nonexistent on these soils, is low.

The results of nitrate nitrogen determinations in desert soils at the periphery of the Bukhara oasis also showed that its content was high, about 25% of the total.

Received August 17, 1960

BIBLIOGRAPHY

1. ANDRIANOV, K.S. 1936. Nitrate solonchak of the Isfarin rayon, Tadzhik SSR. Khimizatsiya sots. zemledeliya. No. 10.
2. DZHUMAYEV, S.M. 1951. Local fertilizers of Turkmenistan. Ashkhabad.
3. DZHUMAYEV, S.M. and A.K. NOSOV. 1948. Genesis of potassium nitrate in the saltpeter-bearing lands of the Turkmenistan plains. Pochvovedeniye. No. 6.
4. KOVDA, V.A. and S.N. SELYAKOV. 1935. Saltpeter solonchaks in Central Asia. Priroda. No. 5.
5. KOSTYCHEV, S.P. 1930. Conclusions of an agricultural-chemical nature from studies of the biodynamics of soils. Mobilization of nitrogen and nitrification in the saltpeter-bearing laylands of Bukhara. Tr. In-ta mikrobiol. Vol. 4.
6. LAZAREV, S.F. 1957. Microflora of soils in the Murgab River delta. In the book: Pochvy del'ty Murgaba i vopr. agrotekhniki khlopchatnika. Tashkent.
7. LYUBAVIN, N.N. 1884. Investigations of Turkestan saltpeter. Zh. Russkogo fisiko-khimicheskogo obshchestva. 16(7).
8. ODINTSOVA, S.V. 1939. Nitrate solonchaks. Tr. Biogeokhim. lab. Vol. 5.
9. ROZANOV, A.N. 1954. New data on the soils of Southern Turkmenistan. Tr. Aralo-Kasp. kompl. eksp. No. 1.
10. SELYAKOV, S.N. 1941. Nitrate-chloride solonchaks and saltpeter deposits in Central Asia. Tr. Pochv. in-ta Akad. Nauk SSSR. 22(2).
11. SELYAKOV, S.N. 1949. Genesis of nitrate solonchaks in Central Asia. Pochvovedeniye. No. 6.

EROSION CONTROL PROBLEMS AND RESTORATION OF SOIL PRODUCTIVITY IN THE UNITED STATES

S. N. RYZHOV, Uzbek Academy of Agricultural Sciences

At the beginning of the present century no mineral fertilizers were used in agriculture in the United States, there was no proper alternation of crops, no grasses were sown, and no forest plantations were established, and therefore the destructive effect of water and wind was very severe. The yields of agricultural crops decreased, while considerable areas of reclaimed lands were not used for agriculture.

Only in 1908 did the U. S. Government call a meeting to discuss the situation at which the President, State Governors, and the outstanding scientists of the country participated (5). The problem of the conservation of the natural resources of the country, including forests, soils, water, and mineral resources was discussed. The expression "soil conservation" was introduced then by the scholarly forester, Overton Price. At the end of 1908 a second meeting on this problem took place. The reports presented by the members of the commission indicated that the main causes for the robbing of the land were erosion and an improper agricultural system. The tendency to make high profits from the sowing of one and the same crop with the least work and expenditures lead to the exhaustion of the soils and the plowing of virgin lands. Natural resources, such as water, forests, and lands, must grow under the activity of man. The key to soil conservation lies in its proper utilization and the regulation of the water regime of a given area, starting from a farm and up to the entire water basin. Recommendations were made at the meeting on conservation of the lands from the harmful effect of erosion and on water regulation:

1) contour plowing on eroded slopes, 2) the construction of reservoirs at the summit of gullies; 3) the establishment of forest shelterbelts and the alternation of plowlands with forest stands; 4) the diversion of excess water by constructing drainways; 5) the sowing of grass as a cover crop to protect the soil surface from erosion; and 6) deep plowing to improve the structure of the soils.

It must be noted that the causes of erosion and severe droughts were already known in Russia at this time and measures had been worked out to eliminate them. But, as it proved, both in Russia and in the United States of America, the first steps in this direction were unsuccessful. The increasing demand for agricultural products during World War I delayed the introduction of measures for land conservation for a long time and even increased its predatory use in the United States. And only in the 20's did Hugh Bennett (1, 4) draw attention to the danger of erosion for agriculture. But another 10 years passed before the government took organization measures to prevent the predatory use of natural resources. In 1933 the Service of conservation of Soil from Erosion was created under the Department of Interior which was renamed Soil Conservation Service and transferred to the Department of Agriculture in 1935. Its first head from 1935 to 1951 was Hugh Bennett. First projects were worked out for soil conservation and water regulation in many states. To realize the soil conservation program the Federal Government covered part of the farmer's expenses.

Starting in 1937 laws were issued allowing the farmers to establish voluntary zonal (local or districts) soil conservation centers. Through these voluntary district organizations the Soil Conservation Service realizes its plans for the increase of soil fertility and the protection of soils from erosion.

Let us note that in 1929 the Government organized 10 experimental erosion control stations at various points of the country and in 1934 a survey was made of the territories damaged by erosion. This survey has been elaborated and supplemented in the following years, primarily during soil investigations, and this permitted the compilation of a map of erosion damage for the whole territory.

On the basis of the foregoing surveys it was established that 20 millions of hectares of plowland were completely destroyed by erosion out of a total of 161 million hectares of cultivated land, and out of 263 million hectares of assessed arable land resources. This area is not suitable for agricultural crops. Approximately the same area is in an almost analogous condition and should be used for grass and tree plantings. There is another 40 million hectares of exhausted land still under agricultural use which has lost part of its upper, fertile layer, and there are more than 40 million hectares land recently subject to erosion. Intense cattle grazing led to strong erosion in forest lands and in natural pastures in the West. We may say that a large part of the 769 million hectares of the total area of the continental United States is already subject to a certain degree of erosion.

In the U. S. A. all the states are subject to water and wind erosion but it is more widespread in the eastern and central parts of the country, where the annual precipitation exceeds 800-1000 mm. In the more dry Western states erosion is somewhat less widespread. However, according to the data of Bennett, wind erosion alone has made 4 million hectares unsuitable for agriculture, while a much larger area was damaged to a lesser degree.

In 1960 the Soil Conservation Service celebrated its 25th anniversary and on this occasion summed up the results of its activities. The Chief of the Conservation Service, Donald Williams, was presented with a bronze medal (6, 7). In the report on the activities during his administration, Williams wrote that in 1958 alone the employees of the Conservation Service together with local organizations surveyed 41 million acres of land under various uses and 12 million acres of pastures, while 116, 000 farmers became members of local soil conservation organizations. The following erosion control measures were taken by agreement in 1958 (8, 9):

1) horizontal contour farming on 2,296, 854 acres; 2) crop rotation for soil conservation on 7,026, 461 acres; 3) cover crops on 4,144,611 acres; 4) strip farming on 768,881 acres; 5) stubble mulching on 3,180,221 acres; 6) pasture improvement over 2,983,556 acres; 7) forest plantings over 752,113 acres; 8) drainage improvement over 1,442,564 acres; 9) planning of irrigated lands over 460,066 acres; and 10) impounding water on 1,290,598 acres.

In addition, 63,060 ponds were built, 40,986 miles of terraces were constructed, 2,383 miles of forest belts were planted, hunting areas were improved, etc. A total of 1,794,411 farmers from 2,796 districts joined national soil conservation societies in the course of 20 years. During this period soil conservation was planned for a total area of 345 million acres, embracing 1,218,433 farms and ranches. At present there are about 100 runoff experiment stations studying surface and internal solid and liquid runoff on various slopes.

Extensive work is conducted on runoff regulation. Complex plans for erosion control have been drawn up for 346 catchment basins in 46 states. The Soil Conservation Service works in close cooperation with the Federal Information Agency, the Agricultural Investigation Service, the Forest Service, the Commodity Stabilization Service, the Bureau of Reclamation of the Department of the Interior, the Army Corps of Engineers, and other departments and educational institutions.

According to the estimate of the Agricultural Research Service, total agricultural production must be increased by 34% by 1975 as compared to 1951-1953 in accordance with the increase in population to 228 millions. However, private land ownership interferes with the planned organization of erosion control and is the cause of the waste of productive land resources. Government interference in the planning of control and prevention of the harmful effects of erosion and land exhaustion is made difficult by private ownership of the land. E. Miman, editor of a Memphis newspaper, wrote that "the right of man to do with the land as he pleases led to soil erosion, and this is nothing else than depriving future generations of the right to use the land populate it" (cited from Wheeler [2]).

During the period of the "New Deal" of President Roosevelt, an Act was passed on the regulation of agriculture under which a Civilian Conservation Corps was organized. More than 3 million unemployed U. S. citizens were occupied in planting trees, building dams for runoff retention, and other erosion control measures. During the period of activity of this organization 2 billion trees were planted, 300,000 permanent and 6 million temporary dams were constructed, 53,000 km of terraces were built, etc. The work was conducted in 45 states, but only on government-owned land. Private land remained untouched and this reduced the effectiveness of the measures. After a short time, in 1942, the activity of the organization was discontinued. According to the data collected by Wheeler (2), the money appropriated for the foregoing measures in the government budget was 191 million dollars in 1954, i. e., two times less than in 1943. The number of farmers participating in soil conservation decreased to 2,577,000 and 1950 and to 1,500,000 in 1954.

In 1956, 175 million dollars were appropriated in the government budget for soil conservation.

Let us examine the actual measures taken in the U. S. for the control of erosion and the increase of soil fertility.

The most important problem is runoff regulation. At the request of local organization, in conjunction with the Soil Conservation Service, plans are made for water conservation installations in an entire catchment basin or only in watersheds and the head of rivers. Such installations consist of water reservoirs (usually small) for catching runoff and gradually releasing the water, feed and discharge channels, and a drainage system, if necessary.

At the same time forests are planted and perennial grasses are sown to prevent erosion and improve water retention in the entire area (a group of farms or ranches). Flow regulation in the upper reaches of water sources alleviates floods and erosion in the lower elements of the water basin. An original method used is that of making meadows of waterways for discharging water. The gullies are filled (if they are eroded), leveled to such a degree as to enable use of agricultural machines, and then sown with perennial grasses which are resistant to trampling. These lands are used for hay or as pastures. We visited some of these erosion control installations at experiment stations and demonstration farms.

The area of the Old Tom River basin in Illinois is 4,665 ha, two-thirds are in Warren county and one-third in Henderson county. There are 65 farms in this area, 17 are privately owned and 48 are leased. The main income is derived from livestock (horned cattle and pigs), while grain farming (oats and wheat) is secondary.

Meliorative and agricultural practices were planned for the basin of this river in 1953 and completed in 1959. The following was done:

1) 15 earth banks were constructed for stabilizing ravines, for flood control, and for water retention; 2) 10 discharge channels were built to stabilize the streams; 3) 4.6 miles of the riverbed were improved; 4) 3.3 miles diversion terraces were built; 5) 9 acres of forest shelterbelts were planted; 6) 33.5 acres of forests were planted; 7) 125 acres of pastures were sown; and 8) 14 acres for game raising were improved.

The program was worked out by the Soil Conservation Service together with local administrations and the Economics Department of Illinois University.

The 88-ha farm of C. Gibson is located in the Old Tom River basin. The soil conservation program was started in 1946, but the planning of all the measures was completed only in 1950. All the gullies, impassable for agricultural machines, were filled in and then converted into tree-shaded pastures and hay fields. Slopes were terraced in 1951. Construction for the regulation of the Old Tom River was begun with the cooperation of other farmers in 1954. Dams, water and diversion channels, small water reservoirs, and ponds for game and for recreation were constructed. Such measures helped to stabilize the stream beds, and alleviated the damage to roads and the formation of ravines. In addition to hydrotechnical installations, proper crop rotation was introduced in the farm, consisting primarily of corn, oats, alfalfa, clover, and timothy. A mixture of alfalfa, clover, and timothy is sown under oats and the next year it is used for hay. The fertilizers used include lime (the soils are acid), phosphates, and nitrogen, as recommended by the Agricultural Chemical Service.

The farm of H. Harris consists of 103 ha and is farmed by sharecroppers. The main income is derived from livestock. The proper grass-cultivation system is used in the fields: two years of corn, one year of oats, and two years of grass. Part of the area is under permanent pasture and part is covered by forests. Erosion control is also carried out on this farm, but without large installations and irrigation systems. The eroded slopes and the shores of ponds are planted with trees, while the gentle slopes are terraced; all depressions are sown with perennial grasses.

The terracing of slopes, the planting of trees, so-called contour farming and the tillage of soils and planting of crops in strips are widely used in the U. S. A. as erosion control measures.

In contour farming the soils are tilled and the crops are planted strictly in a horizontal direction, while strip sowing is done across slopes without strictly adhering to horizontal contours. Row crops alternate with grain crops and grasses in strip and contour farming. With such crop alternation and the terracing of slopes the force of the water is reduced, more water penetrates into the soil, and soil surface erosion decreases.

In regions with heavy precipitation terraces are built at varying slopes, first small and at the end large, about 0.001-0.003; where precipitation is small terraces are built without a slope. Terracing is fully mechanized. Intercepting channels are sometimes built at the end of terraces for the retention of runoff water.

A large assortment of legumes and grasses is used in the U. S. A. in meadows, established on eroded soils, slopes, and gullies, for pastures and hay, depending on climatic conditions, the fertility of soils, and economic needs. *Cynodon dactylon*, *Lespedesa sericea*, and crimson clover are especially resistant to trampling and are widely used in the central and southeastern states. The large variety of grasses allows all sorts of mixed-grass combinations, which are more resistant and yield more than sowings of grasses of one variety.

In addition to alfalfa, red clover, *Agropyrum*, orchard grass, rye grass, and timothy, which are well known and widely used in our country, such grasses as meadow grass, bromegrass, white clover, sweet clover, Bouteloua, *Agropyrum*, canary grass, fescue, beard grass, etc. are used in the U. S. A. for erosion control and for their quality as forage.

Severe erosion and water-logging of soils occur in Tennessee, from the Mississippi River to the border of North Carolina. A considerable part of the state territory (about 45%) is covered by forests. Agricultural crops (cotton, corn, soya, wheat) and grasses cover small areas interspersed by forests. The art of farming is low, and the fields are full of weeds. The annual amount of precipitation is about 1200 mm. The soils are red-yellow podzolic soils which are strongly eroded, sometimes to the parent material. Extensive work on water regulation and the construction of protective dams on the Tennessee River has been conducted in this state.

We examined strip sowings of agricultural crops on slopes, the terracing of slopes, and drainage on the farm of A. B. Harris. It is a livestock farm, covering 110 ha, with 40 milk cows and 40 heifers. A small area is occupied by tobacco. The area is hilly. There are subsurface drains and diversion terraces of a total length of 3 km for diversion of excess water. Stream beds are edged with drains. Most of the plowland is located on slopes, which are either leveled to one gradient or terraced. Crops are sown in strips along the contours. The main crops are corn and grasses (alfalfa and Japanese clover) — two years of corn and two years of grass. The cattle are left most of th year in permanent pastures.

There are large dams for the prevention of inundations during floods along the banks of the Mississippi River to the Gulf of Mexico. Large areas in Missouri, Mississippi, and Arkansas were drained by means of dams and drainage systems and are now being used for growing rice, cotton, corn, and other crops. Ponds, dams, and drainage can be seen in other, smaller systems. Their construction is part of the general system of measures taken by the Soil Conservation Service and the Office of Reclamation.

Experimental work on the reclamation of water-logged lands by leveling and drainage is being conducted at the experiment station in Keiser (Arkansas).

We must especially mention the work conducted at experiment stations on erosion by surface and internal runoff, by irrigation, and by natural precipitation. The experiment station of the Agricultural College of North Carolina University, which we visited, conducts interesting investigations on surface and internal liquid and solid discharge. For this purpose a runoff area is established on a steep slope (about 30°), which is covered with various crops, including perennial grasses. The entire area covers 3.6 acres, while the runoff area is only 1/20 of an acre. There are altogether four runoff areas. They are enclosed with metal sheets driven deep into the ground to prevent the inflow of water from the outside and the escape of water from the area. Runoff is recorded by a special automatic device (water collecter) provided with means for separating solid discharge by particle size. Soil temperature and moisture are measured at the same time. There are observation wells for determining ground-water depth. Subsurface runoff at the very bottom of the slope is also taken into account. Maximum water runoff over various crops is the following.

Liquid surface runoff from fields

Corn field	1.82 ft³ (acre) sec
Wheat field	1.64 " " "
Natural vegetation	1.37 " " "
Perennial grasses	0.58 " " "
Improved pastures	0.42 " " "
Permanent (hay) pastures	0.30 " " "

We visited another runoff area in the experimental field of the Agronomical Faculty of the University of Wisconsin in Madison. It measures natural runoff and runoff from artificial irrigation. The principle of measuring runoff and the experimental setup are approximately the same as in North Carolina. Irrigation is done by sprinkling from a height of 2-3 m. Water is delivered under pressure to this height through pipes and is sprayed more or less evenly over the experimental area. Each area is enclosed by metal strips. The size of the sprinkled areas is about 18 x 3 m, and that of areas without sprinkling, 20 x 8 m. Liquid and solid discharge are caught in an automatic collector.

Observations on the runoff from various relief elements and crops and under various water conservation practices are made at numerous university, state, and Department of Agriculture experiment stations in the United States.

Received December 2, 1960

BIBLIOGRAPHY

1. BENNETT, HUGH. 1958. Principles of soil conservation. Izd. inostr. lit., Moscow.

2. WHEELER, G. SH. 1959. Development of agriculture in the U. S. and its problems. Izd. inostr. lit., Moscow.

3. HIGHSTEAD, A. and G. FIGHT. 1957. Agricultural regions of the United States. Izd. inostr. lit., Moscow.

4. BENNETT, H. H. 1939. Soil conservation. New York-London.

5. TABOR, P. 1960. Early discussions of soil conservation. J. Soil and Water Conservation. 15(3).

6. SCS celebrates its silver anniversary. 1960. Soil Conservation. 25 (12).

7. WILLIAMS, D. A. 1960. An important 25th anniversary. Soil Conservation. 25 (10).

8. WILLIAMS, D. A. 1959. Progress in 1958. Soil Conservation. 24 (7).

9. WILLIAMS, D. A. 1958. Division VI—Soil and water management and conservation. Crops and soils in conservation. Soil Sci. Soc. Amer. Proc. 22 (4).

UNDERSTANDING OF THE TERM 'MANTLE CLAY LOAMS'

P. N. CHIZHIKOV, Agricultural Museum, Moscow State University

The term "mantle clay loams" for a geological formation appeared in the past century, but to this day there is no clear idea as to how this term should be understood. We have in mind not only the idea of their origin, which remains obscure, but primarily views about this formation as a geographical phenomenon with certain known features.

When the special literature mentions the presence in an area of mantle clay loams, or when we read discussions on their origin, we gain the impression that the talk is about a deposit with a well-known appearance and features. But if we ask these authors what we must understand under the term "mantle clay loams" we often obtain such contradictory answers that they cannot be conciliated. At the same time, the more that is written about mantle clay loams, the more difficult it becomes to understand what they are.

In spite of the great importance of understanding the term "mantle clay loams," only brief comments on the question are to be found in our literature. Nevertheless, they clearly show the present situation.

Thus, in the article by Dobrova and Konstantinovich (9) on the Moscow Oblast' it is stated that this is a "collective term," and that mantle clay loams of "various types are found in this region, which apparently differ in genesis and in the period they were deposited." It is mentioned in the paper of Kazakov (12) that: "... the term mantle means that these deposits are problematic as far as type of material and time of deposition are concerned, and are only similar in that they occur under the same geomorphological conditions — in watersheds." In another place the author notes that "this is a rather vague, collective term."

As we can see, the authors mention that it is a "collective term," including various "types of deposits." In their brief definitions they do not pay any attention to the features common to these types of deposits, and only Kazakov points out that there is one thing in common between them — that they occur on watersheds.

B. M. Dan'shin (8) gives a somewhat fuller definition of the term "mantle clay loams": "Under this term we understand boulder-free, non-calcareous clay loams and clays, and less often sandy loams of various origins, which have a common feature in that they are bedded in the form of a continuous deposit extending from watershed areas to fluvioglacial areas, and may be to the third terrace, and also to slopes of ancient gullies."

Agreeing in his views on the origin of these deposits with the views of the foregoing authors, Dan'shin admits that they may differ in texture and may be found not only on watersheds, but also on various relief elements. Such an idea makes the term even more vague. Only two features characteristic of the deposits remain: the absence of boulders and their non-calcareousness.

A more laconic definition is given in the paper of Okhotin and Mazurov (18): "...the term mantle corresponds best to the nature of their bedding." Let us note that such an idea is being voiced more and more often in the literature and in oral statements today. And, strange as it may seem, none of the recent authors pay any attention to it. It would seem that if the term "mantle clay loams" is a collective concept which includes various types of deposits and corresponds only to the nature of bedding, there is no thought in writing about its origin.

Various types of deposits appear most often under the name of mantle clay loams in works on the eastern part of the Russian plain. In particular, Karsnov (15) calls various types of deposits, such as lacustrine, eluvial, deluvial, and proluvial, mantle clay loams. In the entire literature devoted to mantle clay loams we found only once a needed explanation with which we can only agree. In his review of the foregoing paper by Krasnov, Lamakin (16) writes about the inadmissibility of arbitrarily using the term "mantle clay loam," since "...in doing this one confuses the issue of the origin and properties of these interesting formations... And by introducing into the group of "mantle clay loams" deposits of most varied origins Krasnov attributes contradictory properties to them."

And, finally, in a recently published work of Nikolayev (26) it is mentioned that "The term mantle clay loams is collective and obsolete. It means deposits of various origins and ages. It must be avoided when compiling maps of

Quaternary deposits. The view that mantle clay loams are a special genetic type of deposit is erroneous." As we can see, in this word the term "mantle clay loams" is also considered to be collective, mantle clay loams are not recognized as being a special type of deposit; the author considers the term obsolete and recommends that it be avoided.

At the same time, in this interesting work Nikolayev, in contrast to the foregoing authors, gives detailed descriptions of the features of mantle clay loams, which leads to the conclusion that these formations have their own clearly defined features. Unfortunately, the author does not accompany his descriptions by an explanation as to why these features are insufficient to be used as a basis for considering mantle clay loams as special formations. We may ask why we consider another problematic formation — loess, as an individual and special formation on the basis of a number of its features. At the same time it is recommended that the term "mantle clay loams" be abolished.

Thus, everything that has been said about the term "mantle clay loams" leads to this: there is no such special type of deposit or even such a problematic formation as mantle clay loam. Is it not strange that even if there is no special formation under such name, more and more new papers appear every year which are devoted to its origin; even new hypothesis appeared in recent years.

Let us try to find out how such a situation arose and what was the meaning of the term when these formations were first studied and later. For the time being we will make no distinction between the terms "mantle clays" and "mantle clay loams" as related formations.

The term "mantle clay" is first encountered in our literature in the work of Nikitin (24), published in 1886. During this period it was customary in Germany to call various formations found at the surface "mantle": "mantle moraine" (Deckmoräne), "mantle sands" (Decksand), and "layered mantle clays" (Deckthon). Nikitin wrote that "mantle clays" "...are found in Germany and in Russia, primarily in its lake belt." The fact that lacustrine deposits were meant in this case was pointed out by Sokolov (32).

Then the term "mantle clay" appeared in the work of Sibirtsev (33), devoted to the geology of the Oka-Klyaz'ma basin. However, even though Sibirtsev used this term, he related the deposit genetically to a moraine and not to bedding conditions at the surface. He wrote: "On top the moraine is soft and sticky in places, almost free of boulders, and resembles the mantle clay (Deckthon) of the German authors." In this case the question is only about the outward similarity between this formation and lacustrine deposits, while genetically the author relates it to the moraine, located, as the author writes, "on elevated surfaces." Further he writes that the upper moraine is covered "...by a layer of almost boulder-free mantle clay, which can be considered as a deposit of clayey mud from glacial pools or as a product of weathering of morainic marl." In another place he calls this formation "boulder-free mantle clay." But does it follow from this that the new formation distinguished by him, which earlier was connected with the moraine, is considered by him as being "mantle clay?" In our opinion, not. He was the first to attempt to characterize the nature of the formation, for which the only word he could find was in the German literature, and he used this term because it reflects well one of the characteristic features of the formation — its location at the surface. But at the same time we see that in the complete analysis of this formation (in order to distinguish it from the moraine) he puts the word "boulder-free" first. The word "mantle" in this new formation he gives the same meaning as in his other expressions: "lowland mantle clay," and "mantle sands."

At the same time, even before the term "mantle clay" appeared in his works, Sibirtsev described a new formation covering the moraine in sheet 72 of the geological map — loess-like clay loam. He wrote about the origin of loess-like clay loams that the weathering of the moraine "leads also to the formation of various types of loess-like formations." As we will see later, the concepts of mantle clay loams and loess-like clay loams will be intermixed all the time.

Let us note that the merit of distinguishing loess-like clay loams from a moraine belongs not as much to K. D. Glinka, as certain investigators have it, as to N. M. Sibirtsev. Sibirtsev wrote about loess-like clay loams of the Klyaz'ma River 10 years earlier, and also pointed to their presence in the upper reaches of the Dnepr River, where Glinka worked later.

Even earlier, Dokuchayev in his works about Nizhniy Novgorod called the loess-like clay loam on the left bank of the Volga River (which was later called by local investigators mantle clay loam) "northern clay loam" to distinguish it from the "transitional," loess-like calcareous clay loam of the right bank. However, because it was not accepted in our literature, the term remained unnoticed. At the same time such a name makes great sense: according to the idea of Dokuchayev on the zonality of deposits, he placed it in the right place.

Later the concept of mantle clay loams developed during soil investigations in Smolensk Government. At the beginning Glinka (5) described loess-like clay loams as a separate formation. The deposit was called loess-like clay loam both by him and by his collaborators Abut'kov (1), Tumin (35), and Kostyukevich (14) who described the deposit well. It would seem that the term "loess-like clay loams" should have been used for the deposit from then on. But, in examining its origin in his work of 1903 on the Sychev district, Glinka (6) wrote that it "may be considered as "mantle boulder clay," in another work he called the deposit "loess-like mantle clay loam." Glinka did not give an explanation of why he called the deposit by different names. Later Khimenko (38) in discussing the views of the investigators of Smolensk Government on the origin of loess-like clay loams, calls the deposit only mantle clay loams. From this time on many investigators attached a genetic meaning to the term "mantle clay loams."

The designation of one and the same deposit both by mantle and loess-like clay loams, as it was used in the investigations in Smolensk, began to appear in a number of works devoted to other regions, in which both terms acquired a different meaning. In examining designations on maps, we find that the same deposit in one and the same region is called mantle clay loam by one author and loess-like clay loam by another. At the same time such an understanding of the terms led to the amalgamation of both terms into one — loess-like mantle clay loam. This fuller term first appeared in the work of Glinka, then was repeated by Chernyy (37), and then later by Gerenchuk (4), Pogulyayev (28), Salov (31), and others.

But simultaneously with this view other ideas appeared according to which these terms relate to different deposits. Thus Sheglov (39) thought that mantle clay is a more sandy deposit occupying an intermediary position between a moraine and loess-like clay loam. The same was believed by Ponagaybo (29) of the Moscow Oblast' and by Saks (30) for Belorussia. A closer acquaintance with these works shows that they actually discuss a somewhat sandy, but not loess-like deposit.

A. I. Zhirmunskiy (11) considered mantle clay loams as one of the stages of formation of loess-like clay loam. R. S. Il'in believed that loess-like clay loam developed from mantle clay loam and Berg (2) pointed out that these are different deposits, even though they are related by gradual transitions. Moskvitin (22) considered mantle clay loams as separate formations. Moskvitin's mention that in their lower part they may be loess-like is worth special attention. At a conference on mantle clay loams held by the Moscow Society of Nature Investigators, and even earlier in the foregoing work on structural clays we showed that the largest majority of investigators consider the upper part of loess-like clay loam, modified by soil formation, as mantle clay loams and clays. In this case, if the profile is not deep (down to 150 cm) or the loess-like clay loam is shallow, the investigators see a clayey illuvial horizon and not the deposit. In the initial state of development of soil science, when the concept of illuvial accumulation did not yet exist, and the layer at a depth of less than 1 m was considered as "subsoil," it is only natural that Sibirtsev found a similarity between this clayey layer and the lacustrine mantle clays of the Germans. Also, when the thickness of the loess-like clay loam is about 2 m and more, it is very improbable that even an inexperienced investigator would call it mantle clay.

However, because the layer at a depth of 60 cm and approximately down to 180 cm is enriched with clay particles leached from above (and partly as a result of weathering) and acquires an appearance inherent to an illuvial horizon, it does not lose its loess-like texture, but becomes clayey (more precisely, fine clay loam).

On the basis of the foregoing we conclude that the majority of the investigators attribute the names loess-like clay loam and mantle clay or clay loam to a coarse silt deposit in which the loess particle content varies from about 45%-60% and more. At the same time the investigators approached this formation from the genetic point of view, trying to establish its origin.

Together with such views on mantle clay loam another view arose, which we discussed at the very beginning and which related the designation "mantle clay loams" to the conditions of their bedding at the surface. From this point of view earlier investigators wrote about "mantle sand" and "mantle sandy loam," including Nikitin (21), Shcheglov (39), and later Danilovskiy (7), Mazurov (19) and others. Gerasimov and Markov (3) say that the term "mantle deposits" "... is usually used to designate clayey, clay loam, or sandy (sandy loam) deposits." Trofimo (36) uses the term "mantle loess."

From this it follows that the use of the word "mantle" to designate a deposit is very inconvenient. It leads to the confusion of various concepts — lithological-genetic and the concept of bedding conditions. To return to that individual formation of which we speak it is necessary to accompany the word mantle by the term "clay loam."

But would any clay loam at the surface be the clay loam of which we speak? It appears that even in the use of the word clay loam we encounter a great difficulty, it may also lead to uncertainty. For instance, Muratov (23) include in the concept clay loams of such known types of deposits as deluvium, proluvium, alluvium; as if only these types can be clay loam. It is well known that a moraine, and lacustrine and other deposits may also be clay loam. Even though the foregoing author writes that his work "... permits one to a certain degree to approach the solution of the complicated problem of the origin of mantle clay loams," actually it complicates this problem even more. Let us note that in the works devoted to the eastern half of the Russian plain, starting with those of Kassi (13), well known types of deposits are often called mantle clay loam. Thus, if we should disregard the earlier views of the majority of the investigators and agree with more recent views, it actually proves that the term "mantle clay loam" is a collective term.

Finally, if for a long time the opinion prevailed and was authoritatively substantiated in the works by V. V. Dokuchayev, A. D. Arkhangelskiy, and L. S. Berg that mantle clay loams are non-calcareous deposit, confined to the northern part of our plain, nowadays we encounter another concept. Thus, for instance, Mil'kov (20) calls loess-like or, as he write, "loessified," i. e., calcareous clay loam in the south of Ryazan' Oblast', mantle clay loam, and Osokin (27) calls the same deposits in the Voronezh Oblast' mantle clay loam. Under the name "loess-like mantle clay and clay loams" Lukashev (17) describes deposits in the Don-Voronezh watershed, in the Trans-Volga region, and farther, starting from the Kama River in the north to Uzeni in the south, and even in southern Ukraine and in the Crimea.

We can see from the foregoing how confused the understanding of the term "mantle clay loam" is.

We can name three reasons which led to this situation. First, the absence of a connection between the authors and these investigators who laid the foundation of the study of the given formation. Secondly, the term "mantle clay loam" is unfortunate and leads to the confusion of various concepts. Thirdly, these formations under the conditions of the forest zone are modified to a great depth by soil formation.

Having brought this problem under discussion we believe that in order to solve it a number of conditions are necessary which would lead to a certain unity of opinion. First of all, as was established at the very beginning and by the most recent investigations, the foregoing deposit is geographically confined to the northern forested part of the country. It is not calcareous.

When the first studies on mantle clay loam were made it was established that the deposit has a loess-like texture: this has been confirmed recently by a great number of quantitative analyses. Such coarse, homogeneous silty clay loams with a comparatively small content of sand particles have another origin, it would seem, than sandy clay loams having another type of texture. Therefore we should not speak of any clay loam, but of coarsely silty, loess-like clay loam.

As we can see from the foregoing work of Nikolayev, the deposit has many features which in combination make it a special formation characteristically found in watersheds. In the "Map of soil-forming parent materials of the USSR," recently compiled by us (38), it is well (and interestingly) defined geographically.

Since the term "mantle clay loams" is uncertain and is a mixture of concepts, it must be dropped. Instead we could use one of the following two:

1. In order to retain a connection with former designation, we should leave the word "mantle" and call the deposit loess-like mantle clay loam. Such a definition eliminates the possibility of using this term in relation to any other clay loam located at the surface.

2. Call the deposit non-calcareous, loess-like clay loam, which, in our opinion, is more accurate even though it is unusual. This term corresponds to the "northern clay loam" of V. V. Dokuchayev.

If we call the deposit loess-like mantle clay loam, we do not eliminate the possibility of using the same name for the southern calcareous loess-like clay loams, and consequently, do not draw a line between northern and southern loess-like clay loams, while the calcareousness of a deposit is a very important feature both from the theoretical as well as from the practical points of view.

Conclusions

1. The term "mantle clay loam" appeared in our literature when the soils of the northern part of European Russia were studied. At first this term was related to a deposit with well-defined features (clay loam, loess-like texture, the absence of carbonates, and bedding at the surface). At the same time several hypotheses were advanced on the origin of this formation. Later, a considerable number of investigators got away from such an understanding of the term, without observing successiveness. The opinion arose that the term expressed only one of the characteristics of the deposit — its location at the surface.

2. At the present time the understanding of the term "mantle clay loam" is very confused. This situation was created by the fact that the term "mantle clay loam" is a poor choice, leading to the confusion of various concepts, and it should be abandoned.

3. A large amount of factual material on the lithology of this formation has been collected in recent times; geographical data give it a definite place on the map of the country.

4. The term non-calcareous loess-like clay loam corresponds best to the lithology and location of this deposit (as long as its origin remains unsolved).

Received July 18, 1960

BIBLIOGRAPHY

1. ABUT'KOV, A. B. 1911. Brief outline of soil investigations in the Smolensk and Krasnensk districts.

2. BERG, L. S. 1936. Physiographic (landscape) zones of the USSR. Pt. 1.

3. GERASIMOV, I. P. and K. K. MARKOV. 1939. The glacial period in the USSR. Tr. In-ta geografii. No. 33.

4. GERENCHUK, K. I. 1939. Solifluction as a factor in the formation of mantle clay loams on moraines. Uch. zap. Moskovskogo Gosudarstvennogo Universiteta. No. 25, Geogr.

5. GLINKA, K. D. 1901. Vyaz'ma district. Materials for the evaluation of land in the Smolensk Government, Vol. 1, No. 2.

6. GLINKA, K. D. 1903. Preliminary report to the zemstvo of Smolensk Government on soil and geological investigators in the Vyaz'ma and Sychev districts. Vol. 1, No. 2.

7. DANILOVSKIY, I. V. 1931. Geological structure of the Lovata River basin. Tr. Gl. geol.-razved. upr. No. 125.

8. DAN'SHIN, B. M. 1947. Geology of the Moscow Oblast'.

9. DOBROV, S. A. and A. E. KONSTANTINOVICH. 1936. General geological map of Russia, sheet 44, Tr. Moskovsk. geol. tresta. No. 20.

10. BOBRYNIN, B. F. and I. Z. IMSHINETSKIY. 1931. Geomorphological and soil regions of the southeastern part of the Moscow

Oblast'. Moscow.

11. ZHIRMUNSKIY, A.M. 1932. Limits of possible differences of opinion on Post-Tertiary formations in Russia. Vest. Mosk. gorn. akad. No. 2.

12. KAZAKOV, M.P. 1939. Lithology and genesis of mantle formations of the Don glacier tongue. Tr. sovet. sektsii Mezhdunar. assots. po izuch. chetvert. perioda. No. 4.

13. KASSIN, N.G. 1928. General geological map of Russia, sheet 107. Tr. Geol. kom. No. 158.

14. KOSTYUKEVICH, A.V. 1915. Preliminary report on soil investigation in the Bel'sk district, Smolensk Government. Smolensk.

15. KRASNOV, I.I. 1944. Quaternary deposits in the Molotov and Sverdlovsk Oblast's. Geologiya SSSR. Vol. 12.

16. LAMAKIN, V.V. 1948. Critical review of the paper by I.I. Krasnov. Byul. Komissii po izucheniyu chetvertichn. perioda. No. 11.

17. LUKASHEV, K.I. 1955. Main genetic types of Quaternary deposits in the USSR. Minsk.

18. OKHOTIN, V.V. and G.P. MAZUROV. 1951 Mantle deposits on the moraines of the European USSR. Vestn. Leningr. un-ta No. 4.

19. MAZUROV, G.P. 1953. Physico-mechanical properties of glacial soil materials. Uch. zap. leningr. un-ta. No. 169.

20. MIL'KOV, F.N. 1948. Role of soffusion in the development of relief in the Ryazan' Oblast'. Uch. zap. Mosk. gos. un-ta. No. 119, Book 2.

21. MISSUNA, A.B. 1899. Material for the study of the terminal moraines of Lithuania. Materialy k poznaniyu geol. stroyeniya Rossii. No. 1.

22. MOSKOVITIN, A.I. 1933. Materials to the elaboration of the lithology and age of glacial formations. Izv. Mosk. geol.-razv. tresta. 2(2).

23. MURATOV, M.V. 1953. Conditions for the formation of clay loams during the Quaternary period. Byull. Kom. po izuch. chetvert. perioda. No. 19.

24. NIKITIN, S.N. 1886. Post-Tertiary deposits of Germany in their relation to the corresponding formation of Russia. Izv. Geol. kom. 5(3-4).

25. NIKITIN, S.N. and V.A. NALIVKIN. 1896. Hydrological investigations in the upper reaches of the Dnepr River basin before its confluence with the Vyaz'ma River. Tr. eksp. dlya issled. istokov glavneyshikh rek Evrop. Rossii.

26. NIKOLAYEV, N.I. 1959. Problem of the origin of mantle clay loams. Izv. Akad. Nauk SSSR, Ser. geogr. No. 4.

27. OSOKIN, L.S. 1945. Characterization of loess-like clay loams in the Voronezh River basin. Uch. zap. Yaroslavsk. ped. in-ta. No. 6 (geogr. i yestestv.).

28. POGULYAYEV, D.I. 1955. Geology and mineral resources of the Smolensk Oblast'. Smolensk.

29. PONAGAYBO, N.D. 1913. Kolomen district. Materialy po izuch. pochv Moskovsk. gub. No. 3.

30. SAKS, V.N. 1934. Problem of the stratigraph of the glacial deposits in Belorussia. Tr. kom. po izuch. chetvert. Perioda. 4 (20).

31. SALOV, I.N. 1954. Problem of the origin of loess-like clay loams in the Smolensk Oblast'. BMOIP, otdel geologii. 29 (5).

32. SOKOLOV, N.N. 1926. Geomorphological outline of the Volkhov River and Lake Il'men' region. Materialy po issled. r Volkhova i yego basseyna. No. 7.

33. SIBIRTSEV, N.M. 1896. Oka-Klyaz'ma basin. Tr. Geol. kom. 15(2), (sheet 72).

34. SIBIRTSEV, N.M. 1899. Soil science (Textbook).

35. TUMIN, G.G. 1909. Dorogobush district. Materialy dlya otsenki zemel' Smolenskoy gub. Vol. 4.

36. TROFIMOV, I.I. 1945. Loess problem from the lithological point of view. Izv. Akad. Nauk SSSR, Ser. geol. No. 5.

37. CHERNYY, A. 1907. Soils of the Muromsk district in relation to the origin of dark clay loams of the Vladimirsk Government. Pochvovedeniye, No. 2.

38. CHIZHIKOV, P.N. 1960. Map of soil-formin parent materials of the European USSR. Pochvovedeniye, No. 5.

39. KHIMENKOV, V.G. 1914. Brief outline of the geological structure of the Bel'sk district, Smolensk Government. Izv. geol. kom. No. 6.

40. SHCHEGLOV, I.L. 1903. Malenkov district. Materialy dlya otsenki zemel' Vladimirskoy gub. 3 (1).

CAUSES FOR THE FORMATION OF A TEMPORARY WATER TABLE IN FINE CLAY LOAM SOD-PODZOLIC SOILS

M. F. PODVOYSKIY, Agricultural Institute of Leningrad

The fine clay loam sod-podzolic soils of the Northwestern zone develop on flat, elevated relief, and are characterized by excess moisture in spring and autumn and, in certain years, throughout the growing period. The excess moisture of these soils is caused by a temporary water table forming within their profile.

For a number of years we observed the dynamics of the upper level of the temporary water table of these soils in observation wells installed according to the method described by Latysheva (2). The object of our observations was a fine clay loam sod-podzolic soil on a fine clay loam moraine underlain by Cambrian clay in the border zone of the Silurian Plateau.

The main physical and moisture properties of these soils are unfavorable (Table 1). The field and full moisture capacities are practically the same, whereby they are high only in the upper 20 cm. Total porosity decreases sharply with depth and is satisfactory only in the humus horizon. The bulk density of the soil increases sharply along the profile and reaches 1.75 g/cm³ in the layer from 20-30 cm. The high content of clay particles in the upper part of the profile results from a weak process of podzolization, the fine-textured parent material, and the partial gleization of the soil profile.

The upper level of the temporary water table (Fig. 1) fluctuates during the growing period: in the spring and autumn of 1957 and 1958 it was located in the humus horizon, dropping beyond its limits only in the middle of the growing period.

With the deficient atmospheric precipitation in 1959, the upper level of the temporary water table rapidly dropped in spring and did not rise to the humus horizon in the autumn. Our attention was drawn to the fact that the rise of the temporary water table and excess moisture in the fine-textured sod-podzolic soil were due not only to the amount of precipitation, but primarily to its distribution during the growing season. Actually the level of the temporary water table in the soil was the same in May 1957 as in May, 1958 in spite of the fact that the amount of precipitation in 1957 was 700.2 mm, while in 1958 it was 640.5 mm, i. e., 59.7 mm less.

The study of the percolation of individual soil layers (0-20 cm and 20-40 cm), using Klychnikov's instrument (1), revealed that it is highest in the humus horizon, but is also considerable at a depth of 20-40 cm (Table 2).

We investigated the water infiltration and the

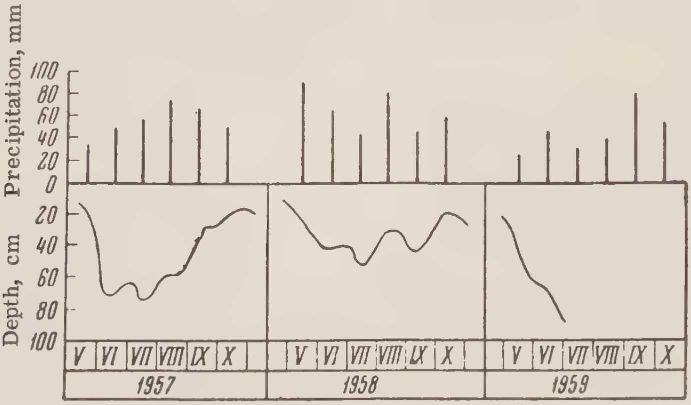

Fig. 1. - Amount of precipitation and level of the temporary water table in the soil.

Table 1

Physical and moisture properties of fine clay loam sod-podzolic soil

Depth, cm	In % of dry soil weight		Total porosity, %	Specific gravity	Bulk density, g/cm³	Content of clay and physical clay, % of dry soil	
	Field moisture capacity	Full moisture capacity				<0.001 in mm	<0.01 in mm
0—10	50,0	52,0	52,6	2,55	1,19	24,6	52,5
10—20	40,1	42,2	46,7	2,60	1,29	22,8	51,2
20—30	17,9	18,5	27,7	2,65	1,75	—	—
30—40	16,6	17,2	26,7	2,65	1,72	—	—
40—50	17,1	17,9	26,6	2,70	1,76	24,4	56,4
50—60	18,0	18,2	25,9	2,68	1,78	—	—
60—70	17,0	18,0	25,2	2,75	1,75	12,9	45,9
100—110	16,3	17,2	24,8	2,75	1,78	10,7	39,5

Note: Comma represents decimal point.

Table 2

Percolation of fine clay loam sod-podzolic soil in the deposit, mm/10 min (average from 4 measurements)

Depth, cm	Measurements									
	1	2	3	4	5	6	7	8	9	10
0—20	775	725	735	690	710	680	638	580	560	520
20—40	710	690	450	420	460	320	340	295	310	295

depth of soil moistening further by determining the rate and depth of chloride movement.

In May of 1958 we selected a plot (4 m²) in the area of the deposit and covered its surface with 12 kg of potassium chloride. Then we took soil samples every 10 cm to a depth of 170-180 cm throughout the growing period (May 25, June 5, August 14, and October 10) at a distance of 2 m, 4 m, and 6 m around the periphery of the plot and determined the amount of chloride in them. At the same time we used a control plot to which no potassium chloride was added and determined the amount of chloride in the soil.

We established that 10 days after the potassium chloride was added the chloride had already moved downward to a depth of 110-120 cm and only in the late autumn did a small amount of it penetrate to a depth of 170 cm. There was also a slow horizontal movement of chloride in the humus horizon, caused by surface and internal flow. The chloride moved only 4 m during the entire period of observation. There was no horizontal movement of the chloride in the lower part of the profile. The water filtered only through channels made by earthworms, of which there were many (Table 3), oriented at a small angle to the soil surface.

There are no such channels at a depth of 100-110 cm and the infiltration capacity of the soil drops sharply.

These observations allow us to conclude that the level of the temporary water table in fine clay loam sod-podzolic soils is governed not only by the amount of precipitation, but also by its distribution. Because of the absence of internal drainage in the lower part of the profile of these soils, precipitation filters into the depth of the soil and fills all porosity. If the amount of precipitation exceeds the volume of porosity, it accumulates within the limits of the soil profile, forming a temporary water table whose upper level rises into the humus horizon.

The level of the temporary water table can

Table 3

Earthworm channels in the soil of the deposit

Depth, cm	Number of channels per m²
40	1360
60	1274
80	788

be lowered only by deep plowing in conjunction with the application of large amounts of organic fertilizers (3).

Received March 25, 1960

BIBLIOGRAPHY

1. KLYCHNIKOV, V. M. 1952. Instrument for determining the water permeability of soils under field conditions. Pochvovedeniye, No. 9.
2. LATYSHEVA, M. N. 1936. Problem of the dynamics of the oxygen content in ground waters. Trudy Pochvennogo instituta im. V. V. Dokuchayeva Akademii Nauk SSSR. Vol. 3.
3. PODVOYSKIY, M. F. 1960. Change in the water-air regime of sod-podzolic, fine clay loam soils during their cultivation. Vestnik sel'skokhozyaystvennykh nauk. No. 2.

INFLUENCE OF THE TIME OF SAMPLE WEIGHING ON THE ACCURACY OF SOIL MOISTURE DETERMINATIONS

M. A. SABITOV, Institute of Power Engineering and Water Economy, Academy of Sciences, Kirgiz SSR

At the present time the most simple and common method of determining moisture is weighing. According to this method the moisture content of a soil sample is determined by the difference in the weight of this sample immediately after it is collected and after it is dried at a definite temperature. However, under field conditions it is not always possible to weigh a soil sample immediately after it is taken and it is often stored for several hours. Sometimes, during mass moisture determinations the samples remain unweighed for a longer period of time.

Because of the foregoing situation the author studied the influence of the time of sample weighing on the accuracy of soil moisture determinations, at the suggestion of M. I. Kaplinskiy.[1]

The soil samples were collected at the Kaindin experimental vertical drainage plot (Kalinin rayon, Frunze Oblast', Kirgiz SSR). Soil moisture determinations were made there in relation to the study of the influence of the removal of water from boreholes on the water balance in the aeration zone. The samples were taken at the beginning and end of pumping from a number of holes (Table 1). The approximate lithological profile of the upper part of the soils and soil materials in the test plot is given below.

0–30 cm. Coarse, light-colored clay loams, riddled with plant roots.

30–80 cm. Medium dark clay loams.

80–120 cm. Fine clay loams with lime concretions.

120–160 cm. Fine sandy loam.

A definite number of boxes with soil were selected for repeated weighing among the number of samples collected during each period.

The soil samples were taken with the D-2 hand soil-tube every 20 cm (except for samples collected in the winter, which were taken every 10 cm), whereby the last sample was taken from below the ground-water level. The weight of the individual samples averaged 30-50 g, not counting the weight of the aluminum can with the lid.

The samples were weighed on technical balances (200 g). The weighing accuracy was within one hundredths of a gram. The samples were first weighed immediately (within 1-2 hr) after sampling. Then the samples were weighed 1, 2, and 3 days after they were taken and then the soil was dried. The cans with soil usually weighed less and less after each weighing. The difference between the weight of the cans with soil at each weighing is apparently due to losses by evaporation.

Table 1

Condition of taking soil samples, 1959

Date taken	Average air temperature, °C.	Number		Ground-water level from the soil surface, m	No. of samples taken
		Spot	Horizon		
Feb. 20	—2÷3	1	12	1,0	12
April 7	+13÷14	4	4—8	0,59—1,15	26
May 19	+12÷13	3	5—9	1,57—1,66	19

Note: Comma represents decimal point.

---

[1] M. A. Zaikina took part in the treatment of the material.

Table 2

Moisture loss by the samples and values of errors with time of determination (% of original soil moisture)

Calculated values	Immediately after sampling	After 1 day	After 2 days	After 3 days
Maximum loss of moisture by samples	0	0,57	0,90	3,13
Minimum loss of moisture by samples	0	0	0	0,06
Average loss of moisture by samples	0	0,24	0,35	0,67
Standard deviation	0	±0,02	±0,03	±0,08
Mean error of individual determination	0	±0,10	±0,14	±0,38
Greatest probable value of moisture loss	0	0,24±0,02	0,35±0,03	0,67±0,08·

Note: Comma represents decimal point.

Table 3

Relationship of moisture loss by samples to the lithological composition of soil material and distribution of moisture with depth

Average depth, cm	Average values of moisture loss by horizons % of original moisture capacity			Average values of moisture by depths, %
	After 1 day	After 2 days	After 3 days	
0	0,395	0,518	1,300	40,50
10	0,234	0,422	0,684	39,30
30	0,200	0,282	0,632	29,30
50	0,166	0,267	0,500	34,50
70	0,196	0,356	0,532	28,40
90	0,227	0,214	0,494	26,30
110	0,246	0,377	0,644	26,80
130	0,276	0,427	0,900	22,62
150	0,285	0,425	0,900	24,04

Note: Comma represents decimal point.

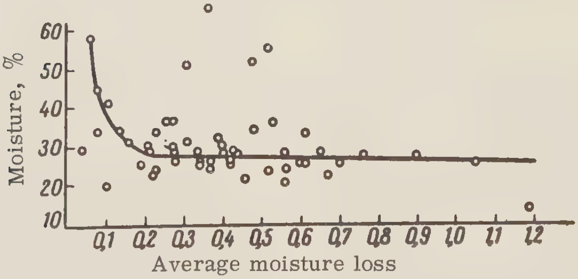

Fig. 1. - Relationship of moisture loss by samples to the moisture of samples taken (percent of original moisture content of soil).

The samples were taken in April (26 samples) and in May (19 samples), weighed immediately, and then weighed daily for 3 days. The samples were stored on the wooden floor of a room at a temperature of 10° -15°C.

We were able to weigh the samples taken in winter (12 samples) only two times, 2 and 3 days after sampling. During the first night the box with the samples was kept on an earth floor at a temperature of 0° + 5°C. Then the samples were transferred from the experimental plot and were stored for 2 days in a laboratory at room temperature.

After the second weighing, the cans with the soil were placed in an electric drying oven for 10 hrs. at a temperature of 105°C. The remaining cans were weighed again and then soil moisture was determined by the usual method.

The moisture content of 57 samples varied on the average from 20%-35%. The high moisture content (50%-60%) of several samples taken at the surface in February and April is attributable to precipitation which took place before sampling.

Below we give the results of the analysis of experimental data and the relation between the moisture losses of the samples and: a) the time elapsed after sampling; b) the lithological composition of the samples with depth; and c) the moisture content of the samples (Table 2).

We obtained the moisture losses for the first, second, and third day after sampling and the mean errors of individual determinations by analyzing the data for samples 39, 43, and 55, respectively.

The data in Table 3 are the average moisture losses of the samples with depth the first, second, and third days after sampling (columns 2, 3, and 4) and average moisture contents. To obtain these values we used the data for samples 39, 43 and 45, respectively. We used 2-7 values to determine the average moisture content and losses with depth at various periods (Fig. 1). When constructing the graph we used the actual moisture content and average moisture losses during three periods for 55 samples.

Conclusions

1. Moisture losses by soil in cans during the first 3 days after sampling are directly proportional to the time elapse after sampling.

2. The decrease of the amount of moisture in the samples 3 days after sampling, as compared to their initial moisture content, is less than 1% of the total moisture content of the soil, which considerably exceeds the accuracy of soil moisture determinations by the weighing method.

Thus, in the case when the samples cannot be weighed immediately after they are collected, the error during their weighing after the first, second, and even third day can be very insignificant and practically allowable.

3. More accurate soil moisture data are obtained by introducing average corrections (Table 2) to the weights measured the first, second, or third day after sampling. These corrections can be used for soils and sampling and storage conditions similar to ours.

4. The pattern of moisture losses from the samples in relation to the lithological composition of the soil is regular (according to data for samples taken in spring).

Evaporation losses are least in samples taken from the middle part of the profile (30-80 cm), consisting of clay loam of medium density.

5. With a soil moisture content of 20%-35% the average moisture losses by the samples in 3 days, as compared with the initial moisture, vary from 0.15%-1.5%, independent of the moisture of the samples.

6. The problem of the allowable sample weighing time under higher air temperature conditions (July-August) and longer transportation requires further investigation.

Received July 7, 1960

ACCURACY OF SINGLE SOIL MOISTURE DETERMINATIONS BY THE WEIGHING METHOD

I. S. SHPAK and M. M. KOSTYUCHENKO-PAVLOVA, North Ukrainian Auxiliary Hydrogeological Station

When investigating the relationship between surface and subsurface waters the problem arises of the necessity of accounting for water accumulating in the aeration zone by seepage from the surface. The quantitative characteristics of water accumulation in the aeration zone can be obtained by soil moisture observations. Parallel observations on soil moisture in the aeration zone in the forest, forest belts, and forest-free areas are one of the means possible of studying the hydrological and agricultural-meteorological role of forests and forest belts.

It is very difficult to make soil moisture observations in the entire aeration zone when the ground water is deep, and therefore soil at a depth from 3-5 m is often sampled only once during various seasons (1, 2, 3).

The moisture values for soils thus obtained are considered sufficiently reliable and are used to determine the changes in moisture content between observation periods. A moisture decrease or increase of 1%-2% and sometimes even of a fraction of a percent in any layer usually is attributed to moisture migration downward or upward. At the same time such changes may be the result of random errors in soil moisture determination.

Let us demonstrate it on the basis of soil moisture observations in a boring 40 m deep at the Desna gage station (Ponornitsa rayon, Chernigov Oblast') in a plowed horizontal area consisting of glacial and fluvioglacial deposits where there is no lateral inflow of water. The observation periods were selected so as to cover the most essential moisture changes in soil and soil material in the course of the year – before soil freezing (December 1, 1957), before spring snow melting (March 1), after the disappearance of snow (April 15) and soil thawing (May 12), at the moment of maximum soil dryness after the harvest of agricultural crops (August 16), and finally, before soil freezing (November 28, 1958). The distance between borings during consecutive periods was 3-5 m. The samples were taken every 20 cm, and during the last two periods, every 10 cm.[1]

We can see from Figure 1, which shows the results of soil moisture observations, that the moisture content generally changes with depth depending on the lithological composition of the soil and soil material. But within the limits of relatively homogeneous layers there is also a change in moisture content, which, judging by the scatter of the points, is of a purely random nature.

In addition to the random moisture changes within a relatively homogeneous layer, resulting from the different contents of small particles in the sample, the presence of inclusions, sampling conditions and the following treatment, and differences in moisture at one and the same depth during consecutive periods of observation may also be caused by the fact that the samples taken from the layer differ in their water-physical properties. This may result from the inclined position of the upper or lower surface of the layer or from inaccuracies in the determination of depths during sampling.

In the majority of cases one cannot determine accurately at which depths the moisture changes between periods of observation are beyond the limits of fluctuations resulting from random causes by comparing soil moisture values for one and another period of measurement on a graph. However, it can be done by using mathematical statistics (4).

It is clear that we cannot compare soil moisture measured at the same depth during various periods since separate moisture values at a given depth are random. It is more expedient to compare the average moisture of individual layers.

Table 1 shows the moisture changes between measurement periods in 1 m, 2 m, 5 m, and 10 m layers. The reliability of the calculated changes in the average moisture content of individual layers between observation periods (ΔW) may be judged by comparing this average with the error in its determination. We will designate this error as the mean error $M_{\Delta W}$. It is clear that if $M_{\Delta W}$ is of the same order of magnitude as ΔW, the latter is unreliable. In this case the actual moisture change can even have a different sign.

If at a certain definite period the moisture

---

[1] The field investigations were conducted at the Northern Ukrainian State Auxiliary Hydrogeological Stations under the supervision of M. M. Kostyuchenko-Pavlova; the statistical analysis was made by I. S. Shpak.

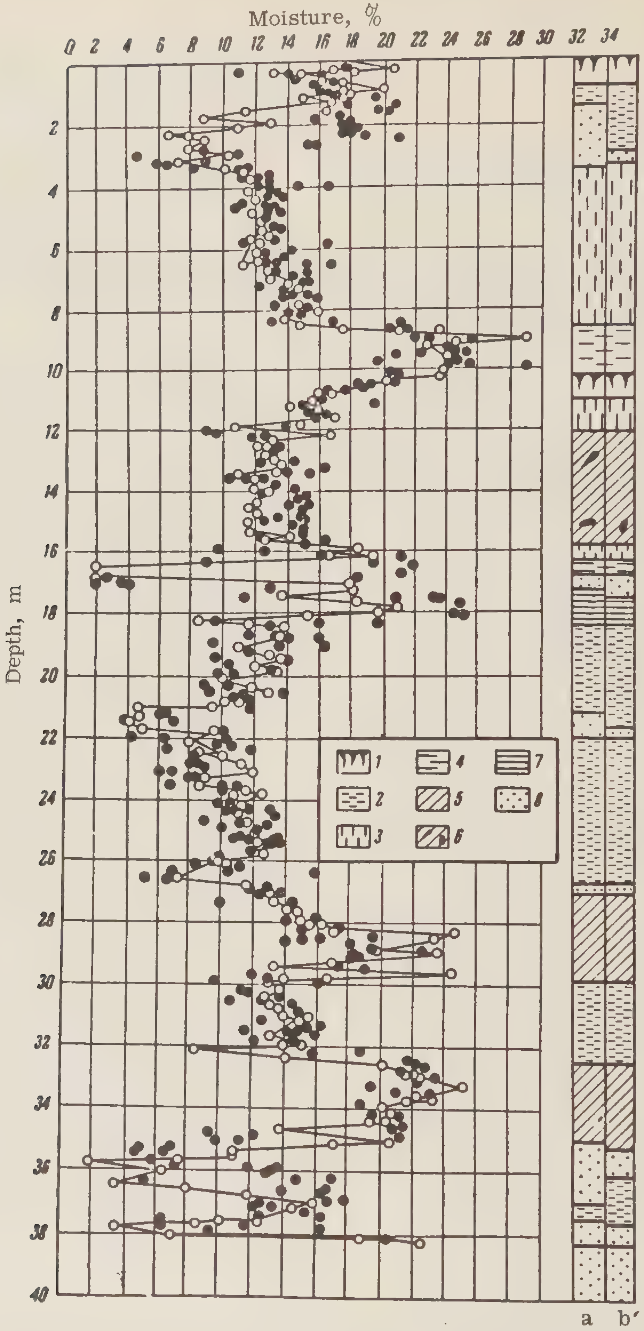

Fig. 1. - Change in the moisture conditions of soil and soil material with depth: December 1, 1957 (light circles, profile is shown in column a), and November 28, 1958 (black circles, profile is shown in column b). 1 - soil; 2 - silty sandy loam; 3 - sandy loam loess; 4 - clay loam loess; 5 - loess-like clay loam; 6 - morainic clay loam; 7 - clay; 8 - sand.

contents at consecutive depths within a given layer are random and independent values, then the mean error in the average moisture content is calculated by the formula:

Table 1

Change in the average moisture content of soil and soil material in various layers and its error ($M_{\Delta W}$)

Limit of the layer, m	Moisture on December 1, %	Moisture change, ΔW					Correlation coefficient		Mean error $M_{\Delta W}$	
		Dec. 1-Mar. 1	Mar. 1-Apr. 15	Apr. 15-May 12	May 12-Aug. 16	Aug. 16-Nov. 28	Dec. 1	Nov. 28	Dec. 1 Mar. 1	Aug. 16-Nov. 28
0–1	17,2	2,1	0,7	—2,4	—4,2	2,4	0,63	0,11	0,8	1,0
2–3	8,7	—0,6	0,3	1,3	0,4	4,8	0,17	0,80	1,4	1,5
4–5	11,3	0,7	0,5	—0,2	—1,5	2,6	0,73	0,20	0,3	0,4
6–7	12,4	1,0	0,9	—1,2	0,2	0,7	0,01	0,04	0,7	0,7
8–9	17,1	1,8	4,0	—1,9	1,8	—4,8	0,90	0,87	1,1	1,0
10–11	20,8	2,2	—1,9	—4,0	0,5	2,3	0,89	0,68	1,0	1,1
12—13	13,2	—0,6	—1,6	—1,9	1,0	—1,2	0,00	0,67	1,3	0,3
14—15	12,0	1,3	—0,2	—0,1	—0,4	1,9	0,13	0	0,1	0,3
16—17	11,5	0,9	—0,6	—4,6	3,0	2,1	0,11	0,56	7,0	4,1
18—19	12,7	2,4	—1,4	3,2	0,4	—1,3	0,70	0,37	1,2	1,7
20—21	10,7	0,4	0,9	—1,4	—0,2	0,4	0,55	0,30	0,7	0,6
22—23	9,4	0,3	—0,2	—0,2	0,5	—1,5	0,45	0,38	0,9	0,6
24—25	11,0	2,0	—2,5	—0,6	2,1	—1,1	0,34	0,04	0,8	0,8
26—27	8,6	1,3	—1,3	1,3	—0,1	—0,1	0,33	0,04	1,6	1,1
28—29	20,0	—2,4	0,5	—3,4	2,1	0	0,06	0,28	2,7	1,2
30—31	13,6	—1,2	2,6	—3,3	3,0	—2,0	0,19	0,18	1,3	1,0
32—33	17,6	—2,3	3,6	2,8	—4,5	2,0	0,93	0,17	1,8	1,1
34—35	19,1	—0,1	—6,2	1,9	1,8	0,3	0,40	0,85	1,5	1,5
36—37	8,5	6,5	—7,9	0,9	—0,3	7,5	0,79	0,25	2,3	1,7
0—2	15,8	0,9	0,8	—2,1	—3,5	4,5	0,32	0,42	0,8	0,6
4—6	11,8	0,2	0,5	—0,4	—0,5	1,6	0,40	0,24	0,4	0,3
8—10	21,2	1,4	3,2	—2,9	1,6	—3,9	0,31	0,81	2,6	0,8
12—14	12,8	0	0,3	—0,6	0,7	—0,5	0,23	0,30	0,7	0,4
16—18	14,5	0,8	0,3	—3,2	2,8	0,6	0,23	0,70	3,0	2,2
20—22	8,0	2,0	0,5	—1,6	1,6	—1,8	0,65	0,67	1,3	0,7
24—26	11,7	0,9	—1,3	—0,3	1,6	—1,3	0,24	0,13	0,6	0,4
28—30	19,3	—3,0	—0,1	—1,8	1,2	0,5	0,36	0,54	2,4	0,8
32—34	20,1	—1,3	0,2	2,3	—3,9	2,8	0,81	0,22	1,2	0,7
36—38	9,4	4,3	—5,9	—1,2	2,8	5,0	0,44	0,41	2,1	1,0
0—5	13,2	0,7	0,5	—1,1	—2,3	3,4	0,73	0,79	0,8	0,4
10--15	14,5	0,9	—0,4	—0,6	—0,6	1,3	0,84	0,74	0,5	0,4
20—25	9,3	1,2	—0,2	—0,6	0,7	—1,3	0,70	0,42	0,5	0,5
30—35	17,5	—0,8	—0,7	1,0	—0,7	0,4	0,71	0,83	1,0	0,6
0—10	14,8	0,7	0,8	—1,4	—0,5	1,0	0,79	0,85	0,5	0,5
10—20	13,9	0,6	—0,3	—0,8	0,4	0,8	0,45	0,69	0,6	0,4
20—30	12,9	0	—0,6	0	0,6	—0,8	0,76	0,79	0,5	0,5

Note: Comma represents decimal point.

$$M'_W = \pm\sqrt{\frac{\sum_{i=1}^{n}(W_i-\bar{W})^2}{n(n-1)}},$$

where W_i is the moisture of the soil and soil material at all depths sampled in the given layer, $\overline{w}$ is the average moisture of the layer, and n is the number of samples taken from the layer.

Most often, however, the moisture content of the soil and soil material, in addition to random changes in its general course, also changes in one direction with depth (increases or decreases); consecutive moisture values in such sections are random and dependent values. A change in moisture content of soil and soil material with depth within the layer may be considered as a linear function of depth in the first approximation. In this case the mean

Table 2

Average moisture changes by layers (ΔW) and their absolute ($M_{\Delta W}$) and relative errors $\frac{(M_{\Delta W})\cdot 100}{\Delta W}$.

Layer	Dec. 1, 1957-March 1, 1958			Aug. 16-Nov. 28, 1958		
	ΔW	$M_{\Delta W}$	$\frac{(M_{\Delta W})\cdot 100}{\Delta W}$	ΔW	$M_{\Delta W}$	$\frac{(M_{\Delta W})\cdot 100}{\Delta W}$
1	1,6	1,5	94	2,0	1,1	55
2	1,5	1,5	100	2,2	0,8	36
5	0,9	0,7	78	1,6	0,5	31
10	0,4	0,5	125	0,9	0,5	56

Note: Comma represents decimal point.

error in the average moisture content of the layer in a given period must be calculated by the formula:

$$M_W = \pm M'_W \sqrt{1-r^2},$$

where r is the correlation coefficient, characterizing the relation between the moisture of soil and soil material at consecutive depths in the layer.

The mean error of the moisture change in soil and soil material within the layer between observation periods should be calculated by the formula:

$$M_{\Delta W} = \pm \sqrt{(M_{W_1})^2 + (M_{W_2})^2},$$

where M_{W_1} and M_{W_2} are the mean error of the average moisture of the layer in the first and second periods of observation.

The results of calculations of $M_{\Delta W}$ and ΔM are presented in Table 1. In order to shorten the numerical material, the table gives the statistical characteristics for every second layer and for two periods only.

The changes in moisture in 1 m, 2 m, 5 m, and 10 m layers between observation periods were of the same order, as a rule, as the errors in the determination of the average moisture in individual layers.

A comparison of the mean arithmetic values of moisture changes by layers and their mean errors (Table 2) shows that the change in moisture in the period from December 1, 1957, to March 1, 1958, was approximately equal to the mean errors; relative errors were close to 100%. During the period from August 16 to November 28, 1958, however, the relative errors in the change of average moisture by layers were 31%-56%. In this case, however, considerable changes in the average moisture by layers were due to the fact that the samples taken from depths from 1-3 m and from 36-38 m in the first and second periods of observation differed in their water-physical properties. During the first period fine-grained sand was found at these depths, while during the second period there was silty sandy loam.

The average change in moisture in the entire 38 m layer of soil and soil material during the second period (August 16-November 28, 1958) was 0.7%; if, however, we do not take into account the moisture changes at depths from 1-3 m and 36-38 m, the average moisture change in the remaining layers is only 0.1%.

We can see that the relative errors were inadmissibly large both for layers with water-physical characteristics sharply changing with depth as well as comparatively homogeneous layers. For instance, at a depth from 3.5-8.5 m, where there was a comparatively homogeneous layer of loess, the relative errors for 1 m layers varied from 15%-100%, while they varied from 20%-200% for 2 m layers.

Large errors were also obtained for the second homogeneous layer, lying at a depth from 22-26 m and consisting of sandy loam. Here the relative errors for 1 m layers varied from 40%-300%, while those for 2 m layers varied from 30%-70%.

Thus, no reliable conclusions on the change of moisture conditions from season to season can be made from the changes in the moisture of soil and soil material determined by the weighing method in only one boring; therefore it is inadmissible that moisture measurements be made only once for the purposes mentioned earlier.

In order to obtain reliable values for moisture changes we must either increase the number of samplings when using the weighing method or use another method of measurement.

Our conclusions do not mean that moisture observations in one boring are inexpedient when comparing profiles located in various geomorphological and lithological conditions and also when comparing moisture distribution with depth in a forest and in forest-free areas.

Received December 2, 1959

BIBLIOGRAPHY

1. BOL'SHAKOV, A. F. and V. V. GERTSYK. 1954. Moisture regime of thick chernozems under an oak forest. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 22.

2. VARLYGIN, P. D. 1953. Moisture regime of soils in forests and forest shelterbelts in the steppe. Tr. In-ta lesa Akad. Nauk SSSR. 12.

3. ZONN, S. V. 1951. Moisture regime of soils in oak forests. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 7.

4. ROMANOVSKIY, V. N. 1939. Elementary course of mathematical statistics.

CHRONICLE

ZINAIDA YUL'YEVNA SHOKAL'SKAYA

Soviet and foreign soil science suffered a severe loss: Zinaida Yul'yevna Shokal'skaya, an honored scientist of the RSFSR, doctor of geographical sciences, died on January 24 at the age of 79.

Zinaida Yul'yevna was born in 1882 in Leningrad (then Petersburg) to the family of the well-known geographer, Yu. M. Shokal'skiy. She received her secondary education at a gymnasium, and her higher education at the natural science faculty of the former Institute of Higher Learning for Women, from which she graduated in 1914 in mineralogy and soil science.

At the beginning of the imperialistic war Zinaida Yul'yevna worked in a war hospital and took care of the wounded until 1918. In June 1918 she transferred to the Academy of Sciences of the USSR in the capacity of a learned secretary and scientist with the Commission for the study of the natural resources of Russia.

In 1921, with the active participation of Zinaida Yul'yevna, a soil science division was established in the Commission, which changed into the Soil Science Institute in 1925, and then into the V. V. Dokuchayev Soil Science Institute of the Academy of Sciences of the USSR, where Zinaida Yul'yevna worked in the capacity of chief scientist until 1947.

The scientific and organizational activity of Zinaida Yul'yevna was unusual and versatile. She began with the study of soil in the suburbs of Leningrad and in the Kola Peninsula and later worked on the generalization of soil and geographical material on a number of tropical and subtropical countries. She took part in the work of the Commission on the soil map of Asia, created at the Second International Congress of Soil Scientists in 1930 under the chairmanship of B. B. Polynov; she published a monograph on the soils of India with an accompanying detailed soil map and a vegetation map. Then she compiled soil maps for Indochina and Indonesia.

From 1935-1937 Zinaida Yul'yevna took part in the creation of the World Soil Map, compiled by L. I. Prasolov for the Great Soviet World Atlas, and at the same time studied and generalized soil and physiographic materials on Africa.

The monograph "Soil-geographic outline of Africa with a soil map of Africa" on a scale of 1:20,000,000 was published in 1948.

For this work Zinaida Yul'yevna was awarded the degree of Doctor of Geographical Sciences. The book "Soil-geographical outline of Africa" was translated into foreign languages and became internationally known.

Next she generalized soil-geographical data on South America. The soil map of South America on a scale of 1:17,000,000 with an explanatory text was published in 1957.

These works required extensive study of numerous foreign sources and considerable skill to interpret them from the point of view of the principles of the Soviet school of soil science.

Thus Zinaida Yul'yevna was the first to generalize the most important material on the tropical belt of the earth from the genetic point of view, which was an essential contribution to soil science and physiography.

Having devoted herself to science, Zinaida Yul'yevna found time to teach. She taught soil science at the Geographical Institute and at the Institute of the Mechanization of Agriculture.

The scientific-organizational and scientific-social activity of Z. Yu. Shokal'skaya was as fruitful. She was one of the oldest and outstanding workers of the Museum of the USSR. Zinaida Yul'eva began her work in this field in 1932. Since 1942 she headed the Museum of Soil Science. During World War II and during the blockade of Leningrad, Zinaida Yul'yevna devoted considerable effort to preserve the collection of the museum and almost single-handed she restored the exhibit of the Museum for the celebration of the 220th anniversary of the Academy of Sciences of the USSR.

In 1947 Zinaida Yul'yevna was made the director of the Central V. V. Dokuchayev Soil Science Museum, which became an independent scientific institution of the Academy of Sciences of the USSR.

From this moment on she devoted all her unusual energy to the development and reconstruction of the museum exhibit in accordance with the tasks and achievements of Societ soil science. Under her guidance a new plan for the exhibit was worked out and fulfilled in which, along with extensive exhibits of the soil-geographical zones of the USSR, special attention was paid to the relation between soils and the biological factor and problems of the reclamation and agricultural utilization of soils.

The rapid growth and development of the Museum as an independent scientific-research and cultural institution and its increasing popularity, not only in our country but abroad, are closely related to the activity and services of Z. Yu. Shokal'skaya.

In addition to the Soil Institute of the Academy of Sciences of the the USSR and the Soil Science Museum of the Academy, Zinaida Yul'yevna devoted a lot of time and effort to work in the Geographical Society of the USSR. Being a member of the Learned Council of the Society since 1940, she administered the work of the Society during the two most difficult years (from the autumn of 1942 until the autumn of 1944), acting as vice-president.

Z. Yu. Shokal'skaya did a great deal for the preservation of the library and the valuable property of the Society. Later, being a member of the Learned Council and the Presidium of the Geographical Society of the USSR and a member of the office of the Soil Commission, Zinaida Yul'yevna always took active part in its work.

At the Second Congress of the Geographical Society of the USSR, in 1955, Zinaida Yul'yevna was elected honorary member of the Geographical Society of the USSR. She was considered an authority among the soil scientists and geographers of the Soviet Union and foreign countries and was also widely known in the party organizations of Leningrad.

In Zinaida Yul'yevna we lost an outstanding Soviet woman, who proved herself by her energetic and versatile activity in the fields of science and social work, and by her true patriotism to the Soviet Union, who devoted all her strength, ability, and great knowledge for the benefit of the Motherland.

The collective of employees of the
Central V. V. Dokuchayev Soil Science
Museum, Academy of Sciences, USSR, and
V. V. Dokuchayev Soil Institute, Academy
of Sciences, USSR

NIL PETROVICH REMEZOV

Professor Nil Petrovich Remezov, an outstanding learned soil scientist, head of the Soil Science Department and the Chair of Soil Science at the Biological-Soil Science Faculty of M. V. Lomonosov Moscow State University, and Doctor of geological-and mineralogical science, died suddenly on March 25, 1961 at the age of 62.

Nil Petrovich Remezov was born in 1899 in Moscow to the family of a railroad employee. He graduated from the gymnasium in 1918 and entered the natural sciences department of the Physico-Mathematical Faculty of Moscow University. From 1919 to 1921 he served in the Red Army, and then returned to the university, from which he graduated in 1923 as a soil scientist.

N. P. Remezov began his scientific activity at the Ya. V. Samoylov Scientific Institute of Fertilizers, where he worked until 1936, heading the section of soil science in the last seven years.

The first works of N. P. Remezov in the field of soil science were associated with the large-scale mapping of soils in a number of sovkhozes and experiment stations; at the same time he participated actively in permanent investigations on the dynamics of soil processes conducted at the Dolgoprud experimental field. He devoted special attention to the problems of liming and the development of methods of determining the requirement of soils in lime. The results of these activities found expression in the "Instructions on the liming of soils" and in a number of scientific articles. Later, in 1938, Nil Petrovich, with the collaboration of S. V. Shcherba, published the widely known monograph "Theory and practice of soil liming."

During the period from 1928 to 1933, Nil Petrovich devoted great attention to the development of a number of methodological problems in the field of physico-chemical soil investigations, the study of organic matter, adsorption capacity, and soil colloids. The results of these investigations were described in many publications and reported at the third International Congress of Soil Science.

From 1933, after being elected professor and head of the Chair of soil science and geology of the Bryansk Forest Institute, Nil Petrovich began work on the study of the processes involved in the interaction between forest vegetation and soils. This became the major trend of his future activity. The necessity of setting up and conducting work in this direction issued from the necessities of life and the necessity of scientifically substantiating the ways and means of forest management.

In 1938 N. P. Remezov transferred to the All-Union Scientific-Research Institute of Forest Management where he studied soil formation under forest cover. After having generalized the results of his long-period investigations, Nil Petrovich defended his doctor's dissertation on the theme "Genesis of podzols" at the Learned Council of the Geological-Soil Faculty of Moscow State University in 1941.

Starting in 1938 and working by appointment at the Scientific-Research Institute of Soil Science of Moscow State University, he supervised soil investigations in experimental areas of the sod-podzolic zone. In 1942, Nil Petrovich transferred to Moscow University in the capacity of Professor of the Chair of Soil Science and was dean of the Geological-Soil Faculty from 1942-1945. After 1945 Nil Petrovich devoted himself to teaching and scientific work. The magnitude and nature of the biological cycles of elements in ash and nitrogen nutrition under forest vegetation became the main concern of his investigations. These investigations were accompanied by permanent observations at various points in the forest zone. In these investigations Nil Petrovich enlisted the help of his collaborators and students.

In 1957 Nil Petrovich became a member of the Communist Party of the Soviet Union. In 1958 he was elected as the head of the Chair of Soil Science of the Biological-Soil Faculty of Moscow State University.

He participated actively in the scientific and social life of our country. For a number of years he was a member of the Council of the All-Union Society of Soil Scientists of the USSR, and conducted work on the propagation of scientific and political knowledge.

His "utilization and cycle of nitrogen and ash elements in the forests of the European USSR," written in collaboration with K. M. Smirnova and L. N. Bykova, was published in 1959, giving the generalized results of the first phase of investigations. Several tens of scientific papers and 8 candidate's dissertations were published on this problem by Nil Petrovich, his collaborators, and students.

Being a scientist of a high erudition, he did not limit himself to the study of problems dealing only with forest soil science. He also worked extensively on the creation of new textbooks and scientific manuals, monographs, and outlines of the scientific activity of outstanding soil scientists. Thus, his scientific manual "Soils, their properties and distribution" was published in 1952, his monograph "Soil colloids and the adsorption capacity of soils" was published in 1957, and outlines of the scientific activity of K. K. Gedroyts, D. N. Pryanishnikov, K. D. Glinka, V. V. Gemmerling, and others are also published. In November, 1960 N. P. Remezov sent the manuscript of a textbook on soil science for students of biological departments of universities to the Moscow University Publishing House. He was the author of 105 works. In recent years he began the generalization of the results of his investigations in the field of forest soil science in the form of a monograph. He had already completed a large part of this work, when his sudden death interrupted it.

Nil Petrovich was also a devoted teacher. His lectures were always of a very high standard and full of factual material. He used the most modern achievements of science. Nil Petrovich trained several tens of soil science specialists, about thirty science candidate's and several doctors.

Soviet soil science suffered a great loss in the death of this outstanding scientist who contributed a great deal to the development of Soviet soil science. His activity and numerous scientific works will always remind us of his great and fruitful work, directed toward the benefit of our Motherland.

M. V. Lomonosov Moscow State University
V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR
All-Union Society of Soil Scientists
Editorial staff of "Pochvovedeniye"

List of Works

Soil of the Dologoprud experimental fields. 1925. Tr. Nauchno-Issledovatel'skogo Upravleniya. No. 30.

Soil liming and nitrates. 1924. Tr. Nauchno-Issledovatel'skogo Upravleniya.

Actual reaction of podzolic soil and the effect of liming on it. 1927. Tr. Nauchno-Issledovatel'skogo Upravleniya. No. 42.

Distribution of bacteria in the soil. (In collaboration with A. S. Razumov). 1928. Tr. S"yezda botanikov v Leningrade.

Determination of the lime requirement of soil. 1929. Izd. Novaya derevnya.

Test of field instruments for determining the lime requirement of soils. 1929. Udobreniye i urozhay. No. 1.

Toward the cognition of oxidation and reduction processes in podzolic soil. 1929. Byul. pochvoveda. No. 4-6.

Distribution of microorganisms in the profile of podzolic soil. (In collaboration with A. A. Razumov). 1929. Pochvovedeniye, No. 1-2.

Ueber ungesätigte Böden. 1929. Zeitschr. Pflanzenernähr. Düngung und Bodenk. A. Vol. 13.

Die Ox-Red Prozesse in den Podzolböden. 1929. Zeitschr. Pflanzenernähr. Düngung und Bodenk. Vol. 13.

Influence of liming on the dynamics of soil processes. 1930. Tr. Nauchno-Issledovatel'skogo Upravleniya. No. 65.

Colorimetric determination of the pH during soil investigations. 1930. Sel'khozgiz.

Instructions on liming soils. (In collaboration with D. L. Askinazi et al.). 1930. Sel'khozgiz.

Soil of the southeastern part of the Dolgoprud experimental field. (In collaboration with L. N. Koshel'kov). 1930. Tr. Nauchno-Issledovatel'skogo Upravleniya.

Dynamics of the oxidation-reduction potential in podzolic soils. 1930. Tr. Nauchno-Issledovatel'skogo Upravleniya. No. 77.

Influence of liming on the structure of podzolic soil. (In collaboration with O. I. Izmailovich). 1930. Tr. Nauchno-Issledovatel'skogo Upravleniya. No. 77.

Determination of the adsorbed H-ion. 1930. Tr. Nauchno-Issledovatel'skogo Upravleniya. No. 77.

Determination of the requirement of soils in lime. (In collaboration with D. L. Askinazi). 1931. Sel'khozgiz.

Physico-chemical methods of soil investigation. 1931. Sel'khozgiz.

Work of the Soil Science Department of the Research Institute of Fertilizers. 1932. Pochvovedeniye, No. 1.

Opposite processes as the basis for the genetic development of soils. 1932. Pochvovedeniye No. 2.

Soil-formation processes and soil zones of the USSR. Handbook on fertilizers. 1933.

Chemical properties of soils. Handbook on fertilizers. 1933.

Dynamics of the oxidation-reduction potential in podzolic soils. 1933. Tr. Mezhd. kongr. pochvovedov v Leningrade.

Influence of liming on the microstructure of podzolic soils. 1933. Tr. Mezhd. kongr. pochvovedov v Leningrade.

Beiträge zur Charakteristik der organischen Substanz der Böden der USSR. Mitteilung 1. 1933. Zeitschr. Pflanzenernähr. Düng. u. Bodenk. A. Vol. 30.

Mitteilung 2. 1933. Zeitschr. Pflanzenernähr. Düng. u. Bodenk. A. Vol. 30.

Qualitative composition of organic matter in the soils of the USSR. 1933. Pochvovedeniye. No. 5.

Teachings of Mattson on the laws of the behavior of soil colloids. 1934. Khimizatsiya sots. zemledeliya. No. 6.

Certain data on the adsorption of anions by soil. (In collaboration with M. M. Vlasova). 1934. Pochvovedeniye. No. 2.

About the article of S. Ya. Sushko "Critical analysis of new soil classifications." 1934. Pochvovedeniye, No. 4.

S. Mattson. Soil colloids. (Abridged translation from the English). 1934. Sel'khozgiz.

Beiträge zur Charakteristik der organischen Substanz der Böden der USSR. Mitteilung 3. 1934. Zeitschr. Pflanzenernähr. Düng. u. Bodenk. A. Vol. 36.

Exchangeable cations in the soils of the USSR in relation to certain physico-chemical soil properties. Tr. Sessii Akad. Nauk SSSR v maye 1935.

Exchange cations in the soils of the USSR. Reports for the 3 Int. Cong. of Soil Sci. 1935.

Exchangeable cations in the soils of the USSR. 1936. Tr. Bryanskogo lesnogo in-ta. Vol. 1. Physico-chemical properties of soils in the tea growing regions of Western Georgia. 1936. Tr. Chaynogo in-ta. No. 6.

Soil solutions and soil colloids. 1937. Izd. Bryanskogo lesnogo in-ta.

Theory of the soil-formation process. 1937. Pochvovedeniye. No. 8.

S. Mattson. Soil colloids. (Complete translation from English). 1938. Sel'khozgiz.

Theory and practice of liming. (In collaboration with S. B. Shcherba). 1938. Sel'khozgiz.

Chemical composition and organic substances in forest soils. 1938. Sb. rabot po lesnomy khozyaystvu.

Condition of nitrogen nutrition in pine stands. 1938. Sov. botanika. No. 6.

Adsorption capacity and composition of exchangeable cations in the major soil groups. 1938. Pochvovedeniye. No. 5.

Review of the results of the scientific-research work of the Chair of Soil Science at the Bryansk Forest Institute in the course of five years. 1938. Pochvovedeniye. No. 7-8.

Dokuchayev's soil science as a service to socialistic forest management. 1939. Pochvovedeniye. No. 2.

D. N. Pryanishnikov and the science of the soil. 1939. Pochvovedeniye. No. 4.

Further investigations on the theory of podzol formation. 1941. Pochvovedeniye. No. 3.

Tasks of the Laboratory of Forest Soil Science. 1941. Tr. Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Lesnogo Khozyaystva. No. 24.

Ammonification and nitrification in forest soils. 1941. Tr. Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Lesnogo Khozyaystva. No. 24.

Soils of the Medveditsa River flood plain. 1941. Tr. Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Lesnogo Khozyaystva. No. 25.

Causes for the drying of forest in the Mededitsa River flood plain. 1941. Tr. Vsesoyuznogo Nauchno-Issledovatel'skogo Instituta Lesnogo Khozyaystva. No. 25.

Complex solution of the problem of steppe afforestation. (In collaboration with D. G. Smaragdov). 1943. Pochvovedeniye. No. 3.

Comparative study of methods of extracting humic acids from soil. 1944. Pochvovedeniye. No. 4-5.

Achievements of soil science in the USSR in the last 25 years. 1944. Izd. MGU.

Influence of the work of K. K. Gedroyts on the development of genetic soil science. 1944. Uch. zap. MGU. No. 104, Vol. 2, Book 2.

A. F. Tyulin and his investigations in the field of soil colloids. 1946. Pochvovedeniye. No. 10.

Contribution of K. K. Gedroyts in the development of Dokuchayev's soil science. 1947. Pochvovedeniye, No. 4.

Decomposition of alumino-silicates by soil bacteria. (In collaboration with L. Ye. Novorossova and N. N. Suskhina). 1947. Dokl. Akad. Nauk SSSR. 58 (4).

Process of formation of the podzolic horizon. 1947. Pochvovedeniye. No. 5.

Genesis of podzolic soils. 1948. Pochvovedeniye. No. 4.

Results of work on the study of the genesis of podzolic soils. 1948. Tr. Pochv. in-ta Akad. Nauk SSSR. Vol. 27.

40th anniversary of the scientific and teaching activity of Prof. V. V. Gemmerling. 1948. Pochvovedeniye. No. 7.

Certain results of the study on the role of vegetation in soil formation. (In collaboration with L. N. Bykovoy and K. M. Smirnovoy). 1949. Vestn. MGU. No. 6.

Maintenance and restoration of forests in the flood plain of the lower reaches of the Ural River. 1949. Lesnoye khozyaystvo. No. 7.

Forest-growing properties of the forested districts of the central taiga. 1950. Vestn. MGU. No. 6.

Soils of the pine forests in the forest-steppe and southern forested districts. 1951. Pochvovedeniye. No. 5.

Utilization and cycle of nutrients in an oak forest. (In collaboration with L. N. Bykova). 1952. Vestn. MGU. No. 6.

Fertility of forest soils. (In collaboration with D. G. Vilenskiy and S. S. Sobolev). 1952. Les i step'. No. 5.

Konstantin Kaetanovich Gedroyts. 1952. Sel'khozgiz.

Soils, their properties and distribution. 1952. Uchpedgiz.

Influence of improvement cutting on the forest-growing properties of soils. 1952. Pochvovedeniye. No. 3.

Utilization and cycle of nitrogen and ash elements in aspen stands. 1953. Pochvovedeniye. No. 8.

Role of a forest in soil formation. 1953. Pochvovedeniye. No. 12.

Section on the utilization of nutrients by a forest in the book of Prof. G. R. Eytingen "Forest management." 1953. 5th ed. Moscow.

Biological cycle and the soil-formation process. 1954. Tr. Voronezhskogo gos. zapoved. No. 5.

Biological cycle of nitrogen and ash elements in forest plantations. (In collaboration with L. N. Bykova and K. M. Smirnov). 1955. Tr. In-ta lesa Akad. Nauk SSSR. Vol. 24.

Introductory article to the geographical compendium "Forests and soils of China." 1955. Izd-vo inostr. lit.

Introductory article in the book of Russell "Soils conditions and plant growth." 1955. Izd-vo inostr. lit.

Life and activity of Academician K. K. Gedroyts. 1955. Selected works of K. K. Gedroyts in 3 volumes. Vol. 1.

Description of new methods of soil analysis. (In collaboration with L. Ye. Novorossova). 1955. Selected works of K. K. Gedroyts in 3 volumes. Vol. 2.

Brief history of soil science at Moscow University. 1955. Pochvovedeniye, No. 5.

Relation between soil conditions and types of forests as examplified by the Mologo-Skeksnin forest district. 1955. Pochvovedeniye. No. 8.

Problem of the nature of soil acidity. (In collaboration with D. L. Askinazi and N. P. Karpinskiy) . 1955. Pochvovedeniye, No. 9.

Role of a forest in soil formation. 1955. Acta Pedologica Sinica. 3(2). In Chinese.

In the pages of the journal "Pochvovedeniye" (review of the journal for 1955). 1956. Vestn. Akad. Nauk SSSR, Ser. biologich. No. 4.

Again, the role of a forest in soil formation. 1956. Pochvovedeniye. No. 4.

Role of the biological cycle in soil formation under a forest. 1956. Pochvovedeniye. No. 7.

The role of biological circulation of the elements in soil formation under the forests. 1956. Rapports présentés au VI Congrès International de la Science du Sol. Paris.

Soils, their properties and distribution. 1956. In Ukrainian. Translation of the Uchpedgiz publication, revised and supplemented. "Radyans'ka shkola," Kiev.

Soil colloids and the adsorption capacity of soils. 1957. Sel'khozgiz.

Forest management of the landes of Gascony (France). 1957. Lesnoye khozyaystvo. No. 12.

Academician K. K. Gedroyts. 1957. "Lyudi russkoy nauki." 2d ed.

Relationship between biological accumulation and the eluvial process in the forest. 1958. Pochvovedeniye, No. 6.

Certain results of the study of soil formation in a forest on sandy parent material. 1958. Nauch. dokl. vysshev shkoly. No. 2.

Soil. Encyclopedia for children. Volume on "Plants and animals." 1958.

Konstantin Kaetanovich Gedroyts. 1958. 2d ed. Sel'khozgiz.

Method of studying the biological cycle of elements in a forest. 1959. Pochvovedeniye. No. 1.

Utilization and cycle of nitrogen and ash elements in the forests of the European USSR. 1959. Collective monograph in collaboration with L. N. Bykova, K. M. Smirnova, and A. P. Utenkova. Izd. MGU.

Concept of a soil group. (In collaboration with O. V. Makeyev). 1959. Nauchn. dokl. vysshey shkoly. Biologicheskiye nauki. No. 3.

Problems and methods of studying the biological

cycle of elements. 1959. Sb. dokl. sovetskoy sektsii VII Mezhdunar. kongr. pochvov.

Soil. Encyclopedia for children. 1960. Vol. 4.

Major properties of the soils of the USSR. 1960. Manual on fertilizers. 2d ed.

The most acute problems in the study of the biological cycle and its role in soil formation. 1960. Vestn. Mosk. un-ta. No. 3.

Vladimir Vasil'yevich Gemmerling. 1960. Seriya "Zamechatel'nyye uchenyye Moskovskogo universiteta." Izd. MGU.

BIBLIOGRAPHY

FACTORS OF SOIL FORMATION, GENESIS, GEOGRAPHY, CARTOGRAPHY

1. Agricultural climatic handbook. 1960. Alma-Ata, Kazgosizdat. (Alma-Ata gidromet. observatoriya). For the Aktyuba Oblast'. 150 pp. with diagrs. and maps. For the Semipalatinsk Oblast'. 423 pp. with illustr. and maps.

2. Agricultural climatic handbook. 1960. Leningrad. Gidrometeorologizdat:
   ...for the Bryansk Oblast'. 111 pp. with diagrs. and maps. (Kursk. gidromet. observatoriya).
   ...for the Buryat ASSR. 190 pp. with illustr. (Chit. gidromet. observatoriya).
   ...for the Ivanov Oblast'. 131 pp. with illustr. and maps. (Gor'kovsk. gidromat. observatoriya).
   ...for the Kabardin-Balkar ASSR. 136 pp. with illustr. and maps. (Rostov. gidromet. observatoriya).
   ...for the Lipets Oblast'. 95 pp. with illustr. and maps. (Kursk. gidromet. observatoriya).
   ...for the Maritime Province. 130 pp. with illustr. and maps. (Vladivostosk. gidromet. observatoriya).
   ...for the Tyumen Oblast' (Southern Chechnya). 164 pp. with illustr. and maps. (Omskaya gidromet. observatoriya).
   ...for the Chelyabinsk Oblast'. 156 pp. with illustr. and maps.

3. BABICH, A. D. 1960. Steppe oasis Askaniya-Nova. Characterization of the natural conditions in the region. Khar'kov, Izd. Khar'k. un-ta. 203 pp. with illustr. and maps.

4. BALKOV, V. A. and YU. A. VLASOV. 1960. Characterization of the landscape of the northern part of the Kungur forest steppe. Uchen. zap. (Pe msk. un-t). 15(2):85-91. Bibliog. 9 refs.

5. BONDAREVA, V. YA. 1960. Certain data on mountain-forest soils of the Kuylyu River Valley. Izv. AN KirgizSSR. Ser. yestestv. i tekhn. nauk. 2(10):113-118. Bibliog. 5 refs. Summary in Kirgiz.

6. WANG YÜN-YEN. 1960. Study of loess deposits in China and their comparison with the loess of Central Asia. Izv. vyskh. ucheb. zavedeniy. Geologiya i razvedka. No. 10:3-11. Bibliog. 17 refs.

7. VINOGRADOVA, A. I. 1960. Landscape mapping on the basis of data from air-photo interpretation (the shore of the Tsimlyansk reservoir taken as an example). Laboratoriya aerometodov AN SSSR. Vol. 10:170-177, with tables. Bibliog. 6 refs.

8. GRAZHDAN, P. YE., YE. S. SBORSHCHIKOVA, S. D. STATIYEVA, and T. A. SKOROD'KO. 1960. Characterization of sierozem-meadow (sasa) soils of the piedmont plain of Kopet-Dag. Tr. Turkm. s.-kh. in-ta. 10(1):99-105.

9. DZHUMAYEV, O. M. 1960. Characterization of soil in Western Turkmenistan. Tr. Turkm. s.-kh. in-ta. 10(1):85-97. Bibliog. 10 refs.

10. KOLYAGO, S. A. and G. I. KONEV. 1960. Soils under cedar stands in the region of the lower reaches of the Ob' River. Tr. po lesnomu khoz-vu Sibiri. No. 6:89-100.

11. KONOPLYANTSEV, A. A. 1960. Zonality and azonality of ground waters. Sov. geologiya. No. 12:86-97. Bibliog. 16 refs.

12. KRIGER, N. I. and K. P. KRIEGER. 1960. Origin of loess in North America. (Literature survey). Byul. Komis., po izuch. chetvertichnogo perioda. No. 25: 71-92. Bibliog. pp. 90-91.

13. KRINITSKAYA, R. R. 1960. Certain problems of the dynamics of the soil and vegetation of estuaries (taking the Western Caspian region as an example). Izd. AN KirgizSSR. Ser. yestestv. i tekhn. nauk. 2(10):91-105, with maps. Bibliog. 12 refs. Summary in Kirgiz.

14. KRUPENIKOV, I. A. 1960. Buried soils of the Lower Trojan wall and certain problems of paleopedology. Okhrana prirody Moldavii. No. 1:55-69. Bibliog. 20 refs.

15. KRUPENIKOV, I. A. 1960. Chernozems of the Danube region of Moldavia and Ukraine. Izv. Modav. filiala AN SSSR.

No. 6:3-23. Bibliog. 38 refs. Summary in Moldavian.

16. KRYLOVA, A. I. 1959. Soils of the Krasnoznamensk rayon of Kaliningrad rayon of Kaliningrad Oblast'. Author's summary of his dissertation for a candidate's degree in agricultural sciences (Vsesoyuzn. n-i. in-t udobr. i agropochvovedeniye). Moscow. 18 pp.

17. KUCHERENKO, V. D. 1960. Study of soil-formation processes in the karst regions of the Southern Urals. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 4:215-220. Bibliog. 5 refs.

18. LAUYENKRAPCHA, E. K. 1960. Devonian deposits in the Latvian SSR as soil-forming parent materials. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Latv. s.-kh. akad.). Riga. 37 pp.

19. NITSENKO, A. A. 1960. Classification of bog complexes. Botan. zh. 45(11):1630-1639. Bibliog. 8 refs.

20. RUDNEVA, YE. N. 1960. Soil of the Trans-Carpathian region. Moscow, Izd. AN SSSR. 229 pp. with illustr. and maps. (Pochv. in-t im. Dokuchayeva). Bibliog. pp. 221-228.

21. SEMENOVA, N. N. 1960. Soil regionalization of the shores of the Tsimlyansk reservoir according to materials from aerial photographic surveys. Tr. (Laboratoriya aerometodov AN SSSR). Vol. 10: 190-198. Bibliog. 5 refs.

22. SKURTUL, A. G. 1960. Soil of the Kogil'nik River flood plain and prospects for its further reclamation. Tr. Moldavsk. n.-i. in-ta oroshayemogo zemledeliya i ovoshchevodstva. Vol. 2:25-38. Bibliog. p. 36.

23. TOLCHEL'NIKOV, YU. S. 1960. Experimental large-scale mapping of soils from aerial photographs by the method of key areas. Tr. (Laboratoriya aerometodov AN SSSR). Vol. 10:90-98.

24. UDACHIN, S. A. Land resources of the USSR and its utilization. Moscow, Sel'khozgiz. 251 pp. with diagrs. and 1 illustr.

25. FRIDLAND, V. M. 1960. First soil map of the Democratic Republic of Vietnam. Vestn. AN SSSR. No. 11:98-100.

26. CHAZOV, B. A. 1960. Study of natural landscapes in the southern part of the Perm Oblast'. Uchen. zap. (Permsk. un-t). 15(2):61-73. Bibliog. 8 refs.

27. CHAZOV, B. A. Typology of Landscapes in the southern part of the Perm Oblast'. Ibid. pp. 75-83. Bibliog. 9 refs.

28. CHIRVINSKIY, I. A. 1960. Large-scale soil investigations. Zemledeliya. No. 12:83-86.

29. SHISHKINA, O. V. 1960. Change in the salt composition of sludge waters in the process of diagenesis. Tr. Okeanogr. komis. (AN SSSR). 10(2):13-20. Bibliog. 6 refs.

30. EDILYAN, R. A. and N. K. KHITRYAN. 1960. Characteristization of bare soils on the shores of Lake Sevan. Yerevan. Izd. Gl. upr. s.-kh. nuaki Min-va s.-kh. ArmSSR. 121 pp. with illustr. and maps. In Armenian.

31. BIDWELL, C. W., R. A. BOHANNEN. 1960. Saline County Kansas promotes its soil survey. J. Soil Water Conservat. 15 N 3, pp. 121-23.

32. BOWSER, W. E. 1960. The soils of the Prairies. Agric. Inst. Rev. 15, N. 2, pp. 24-26.

33. BUNTLEY, G. J., R. L. RAPENDICK. 1960. Worm-worked soils of Eastern South Dakota, their morphology and classification. Soil Sci. Soc. America Proc. N 2, pp. 128-32.

34. CANN, D. B., J. F. G. MILLETTE. 1960. Soils of the Appalachian Region. Agric. Inst. Rev. 15, N 2, p. 44-47.

35. DRAGHETTI, A. 1960. Agricultural lands of the Emilian Appennines. Modena Cam. di Com. indus. e Agr. B. Mens. 66, N 2, p. 129-45.

36. EHRLICH, W. A., W. ODYNSKY. 1960. Sols developed under forest in the Great plains Region, Agric. Inst. Rev. 15, N 2, pp. 29-32.

37. ELFORD, C. R., R. H. SHAW. 1960. Climate of Iowa; Soil themperatures at Ames. Iowa Agr. Exp. Spec. Rep. 24 p. 1-70.

38. FARSTAD, L., C. A. REWLES. 1960. Soils of the Cordilleran Region. Agric. Inst. Rev. 15, N 2, p. 33-36.

39. LUTHIN, J. N., K. BAGHOTT. 1960. Soil salinity on Tulelake lands. California Agricul. 14, N 3, pp. 12.

40. MOSS, H. C. 1960. Mapping our soils; the work of Canadian soil surveys. Agric. Inst. Rev. 15, N 2, pp. 13-14.

41. NOWOSAD, F. S., A. LEACHEY. 1960. Soils of the Arctic and Sub-Arctic Regions of Canada. Agric. Inst. Rev. 15, N 2, pp. 48-50.

42. PAWLUK, S. 1960. Some podzol soils of Alberta. Canad. J. Soil Sci. 40, N 1, pp. 1-14.

43. RUSSELL, J. S. 1960. Soils of South Australia: the deep sands. Agric. J. South. Austr. Dept. 63, N 7, pp. 298-307.

44. SETH, S. K., J. S. P. YADAR. 1960. Soils of the tropical moist evergreen forest of

India. Indian Forester, 86, N 7, pp. 401-13. Bibliog. 22 ref.

45. TROLL, C. 1960. The relationship between the climates, ecology and plant geography of the southern cold temperate zone and of the tropical high mountains, Proc. Royal Soc. Ser. N 949, p. 529-40. Bibliog. 8 refs.

46. WHITE, J. L. 1960. and oth. The influence of parent material and topography on soil genesis in the midwest. Bull. Purduc agric. Exp. Sta. Res. No. 693, 20 pp. Ref.: Soils and Fertilizers N 5, 2127.

47. YADAV, J. S. P. 1960. Soils of the dry zone of India. Indian Forester, 86, N 5, pp. 274-95.

SOIL MINERALOGY

48. LUKASHEV, K. I. and S. G. DROMASHKO. 1960. Certain data on the mineralogy of the clay fraction of loess deposits in Belorussia. Dokl. AN BSSR. 4(11):469-473. Bibliog. 5 refs.

49. BLACKMORE, A. V., B. P. WARKENTIN. 1960. Swelling of calcium montmorillonite. Nature, 186, N 4727, p. 823-24.

50. EMERSON, W. W. 1960. Complexes of calcium-montmorillonite with polymers. Nature. 185 N 4724, p. 573-74.

51. ESQUEVIN, J. 1960. Les silicates de zink: (étude de produits de synthèse et des minéraux naturels). Compt. rend. Acad. agric. France. 46, N 9, pp. 563-64.

52. GRIM, R. E. 1960. Some applications of clay mineralogy. Amer. Mineralogist. 45, N 3-4, pp. 259-69. Bibliog. pp. 268-69.

53. HAANG, G. K., P. F. KERR. 1960. Infra-red study of the carbonate mineral. Amer. Mineralogist, 45, N. 3-4, pp. 311-24.

54. HAY, R. L. 1960. Rate of clay formation and mineral alteration in a 4,000-year-old volcanic ash soil on St. Vincent B. W. I. Amer. J. Sci. 228, pp. 354-68.

55. MIDGLEY, H. C., C. M. MIDGLEY. 1960. The mineralogy of some commercial vermiculites. Clay Minerals Bull. 4, N 23, pp. 142-50.

56. MITCHELL, W. A. 1960. A method for quantitative mineralogical analysis by X-ray powder diffraction. Mineral. Mag. 32, N 249, p. 492-99.

57. WARSHAW, C. M. and oth. 1960. Changes affected in layer silicates by heating below 550°C.

PHYSICAL PROPERTIES OF SOILS AND METHODS OF INVESTIGATION

58. ALOV, A. S. 1960. Soil structure as a factor in fertility. Moscow, Izd. Min-va s.-kh. RSFSR. 128 pp. with illustr. Bibliog. 28 refs.

59. ANDREYEV, O. B. 1961. Soil moisture meter using gamma rays. Zemledeliye. No. 1:59-60.

60. BABUSHKIN, L. P. 1960. Field microprobe for measuring photosynthesis and respiration. Tr. Mold. n.-i. in-ta oroshayemogo zemledeliya i ovoshchevodstva. Vol. 2:211-216.

61. BABUSHKIN, L. N. Field transpirometer. Ibid., pp. 203-210.

62. BESPALOV, D. P. 1960. Remote installation for measuring soil temperature. Tr. Glav. geofiz. observatorii. No. 103-32-44. Bibliog. 8 refs.

63. RESPALOV, D. P. Method and apparatus for the experimental determination of thermal exchange in soil. Ibid. pp. 68-84. Bibliog. 22 refs.

64. GRECHIN, I. P. and CHENG YÜN-SHEN. 1960. Dynamics of oxygen and carbon dioxide of soil air in sod-podzolic soil. Izv. Timiryazevskoy s.-kh. akad. No. 6:68-79. Bibliog. pp. 78-79.

65. DENISOV, P. S. 1961. The role of snow in wetting fields of virgin and abandoned lands. Zemledeliye. No. 1:12-17.

66. ZHITETSKAYA, F. D. 1960. Investigation of bound water in peat by various methods. (Kalininskiy torf. in-t). Moscow. 18 pp.

67. ZATENATSKAYA, N. P. 1960. Problem of bound water in clay deposits. Dokl. AN SSSR. 135(4):944-947. Bibliog. 7 refs.

68. IOVENKO, N. G. 1960. Hydrophysical properties and the moisture regime of soils in the Ukrainian SSR. Edited by A. M. Kekukha. Leningrad, Gidromeoizdat. 352 pp. with illustr. and maps. (Ukr. n.-i. gidrometeorol. in-t). Bibliog. 642 pp.

69. KASPIROV, A. I. 1960. Forms of soil moisture and the physical state of soil in relation to mechanical tillage. S. kh. Sev.-Zap. zony. No. 12:21-24.

70. ORLOV, D. S. 1960. Polarographic method of investigating soils. Brief instructions to practical exercises. Moscow. Izd. Mosk. un-ta. 132 pp. with illustr. Bibliog. 43 refs.

71. POPOV, L. V. 1960. Methods of determining soil moisture. (Tr. Vost.-Sib. filiala AN SSSR. No. 31, ser. biol). Moscow, Izd. AN SSSR. 96 pp. with illustr. Bibliog. pp. 78-95.

72. ROMANENKO, V. A. 1960. Calculation of soil freezing depth from the sum of negative air temperatures and snow depth. Tr. Ukr. n.-i. gidrometeorol.

in-ta. No. 24:27-31. Bibliog. 6 refs.

73. SMOLINA, L. B. and V. YA. VOLKOVA. 1960. Influence of artificial aggregants and humic acid preparations on the aggregation of particles in a typical sierozem. S. kh. Uzbekistana. No. 12:79-82.

74. CHUDNOVSKIY, A. F. 1960. Mathematical method of finding the variable thermal diffusivity coefficient of soil. Inzh. -fiz. zh. 3(12):91-98. Bibliog. 8 refs.

75. SHESTAKOV, I. L. 1960. Certain data on the physical properties of brown forest soils of the central part of the Moldavian SSR. Izv. Moldav. filiala AN SSSR. No. 6:53-64. Bibliog. 7 refs. Summary in Moldavian.

76. SHLEYMOVICH, P. L. 1960. Soil structure and its importance in the increase of soil productivity. (Kazakh. gos. un-t, kafedra pochvovedeniya). Alma-Ata. 192 pp. Bibliog. 126 refs.

77. SHPAK, I. S. 1960. Method of calculating evaporation from soil from total radiation and precipitation. Tr. Ukr. n. -i. gidrometeorol. in-ta. No. 24:38-45. Bibliog. 13 refs.

78. COMBEAU, A. 1960. Quelques facteurs de la variation de l'indice d'instabilité structurale dans certains sols ferralitiques Compt. rend Akad. agric. France, 46, N 3, pp. 109-15.

79. FRAZIER, R. D., A. R. BERTRAND. 1960. Automatic recording of soil moisture and other ecological factors. Agron. J. 52, No. 1, pp. 53-54.

80. HULL, R. D., D. N. CROOK. 1960. 2, N 3, pp. 374-84. Bibliog. 10 refs.

81. JANSE, A. R. P., G. H. BOLT. 1960. The determination of the air-permeability of soils. New Jer. Agric. Sci. 8, N 2, pp. 124-31 Bibliog. 14 refs.

82. LÄG, J. 1960. Observations on special colours of the A$_2$-layer of podzol soils in Norway. Acta Agric. Scand. 10 pp. 45-49.

83. McINTYRE, D. S. 1960. Porosity and microporosity of soils of different ages. CSIRO Div. Soils div. Rep. 2/60, 8 p. Ref. Soils and Fertil. No. 5, pp. 2044.

84. MEYER, A. F. 1960. Effect of temperature on ground-water levels. J. geophys. res. 65, pp. 1747-52.

85. PECK, A. J. 1960. Change of moisture tension with temperature and air pressure: theoretical. Soil Sci. 89, n 6, pp. 303-10 Bibliog. pp. 309-10.

86. PHILIP, J. R. Energy dissipation during absorption and infiltration 2. Ibid.

87. POPA, A., Z. BRATU. 1960. Laboratory tests concerned with the establishment of the influence on the soil structure of synthetic polyelectrolytes, realized in the R. P. R. Rev. Padurilor, 75, No. 1, pp. 16-20.

88. RAUZI, F. 1960. Water-intake studies on range soils at three locations in the northern plains. "J. Range Manag." 13, N 4, pp. 179-184. Bibliog. 9 refs.

89. STOECKELER, J. H., S. WEITZMAN. 1960. Infiltration rates in forzen soils in Northern Minnesota. Soil Sci. Soc. America Proc. No. 2, pp. 136-39.

90. SUNKEL, H. 1960. Über die Porosität von Bodenaggregaten. I. Mitteilung: Eine Methode zur Bestimmung des Substanz — and Porenvolumens von Bodenaggregaten. Z. Pflanzenernähr., Düng., Bodenkunde, 89 (134):I 17-27. Bibliog. 15 refs.

91. TAYLOR, S. A., G. L. STEWART. 1960. Some thermodynamic properties of soil water, Soil Sci. Soc. America Proc. 24, N 4, pp. 243-47.

92. TRICKI, N., B. R. NAGAR. 1960. Synthetic polyelectrolytes as soil conditioners. J. Indian. Soc. Soil Sci. 8, N 1, p. 45-47.

93. VAŚA, J. 1960. Pudni vláhove charakteristiky. Vodohospodársky cásopic. 8 (3):235-43. Bibliog. 18 refs.

94. WHITTLE, R. M., W. J. C. LAWRENCE. 1960. The climatology of glasshouses. 4. Soil temperature. J. Agric. Eng. Res. 5, N 3, pp. 235-240.

95. WILLIS, W. O. 1960. Evaporation from layered soils in the presence of a water table. Soil Sci. Soc. America Proc. N 4, pp. 239-42.

96. ZUR, B., L. W. REED. 1960. Aggregate stability and other properties of a Kirkland silt loam soil. Okl. Agric. Exp. Proceed. Str. p. 346, pp. 1-13.

SOIL CHEMISTRY AND METHODS OF ANALYSIS

97. VESELKINA, R. V. 1960. Dynamics of water-soluble substances in the ground waters of the flat part of the Lenkoran region. Dokl. (AN AzerbSSR). 16(10):973-976. Summary in Azerbaydzhan.

98. DOBROVOL'SKIY, G. V. and I. V. YAKUSHEVSKAYA. 1960. Certain patterns in the distribution of microelements in the soils of river valleys. Vestn. Mosk. un-ta. Ser. 6, Biologiya, pochvovedeniye. pp. 57-70, with tables. Bibliog. 10 refs.

99. YERMOLENKO, N. F. 1960. Soil microelements and colloids. Izd. AN BSSR. Minsk. 290 pp. with illustr. and maps. Bibliog. 427 refs.

100. ZUKHUROV, N. 1960. Oxidation-reduction potential in meadow, bog-meadow,

and bog soils of the sierozem belt. S. kh. Uzbekistana. No. 11:49-53.

101. KOTELKOV, N. Z. and YE. A. ZABURINA. 1960. Microelement content of soils in the Saratov Oblast'. S. kh. Pocolzh'ya. No. 12:37-38.

102. MAKAROV, V. T. and G. M. MILOSLAVSKAYA. 1960. Dynamics of organic matter in sod-podzolic soil under various methods of plowing. Nauchn. dokl. vyshk. kholy. Biol. nauki. No. 4:211-214.

103. PAVLOVA, N. I. and T. M. KHRENKOVA. 1960. Method of determining potassium from natural radioactivity. Zavodskaya laboratoriya. 26(11):1201-1202. Bibliog. 6 refs.

104. RONOV, A. B. and G. A. KORZINA. 1960. Phosphorus in sedimentary rock. Geokhimiya. No. 8:667-687. Bibliog. 33 refs.

105. TROITSKIY, YE. P. 1960. Main problems in teaching microelements in the soil-plant system. Vestn. Mosk. un-ta. Ser. 6. Biologiya, pochvovedeniye. No. 5:48-56. Bibliog. 10 refs.

106. KHOBOT'YEV, V. G. 1960. Biogeochemical provinces with a deficiency of calcium (in the regions of the seat of the Urov enclave Geokhimiya. No. 8:688-696. with maps. Bibliog. 13 refs.

107. BABCOCK, K. L. 1960. Evidence for sodium fixation in salt-affected soils. Soil Sci. Soc. America Proc. N 2, pp. 85-86.

108. COCK, M. G., T. B. HUTCHESON. 1960. Soil potassium reactions as related to clay mineralogy of selected Kentucky soils. Soil Sci. Soc. America Proc. 24 N 4, pp. 252-56.

109. COLEMAN, N. T. and oth. 1960. Phosphate-sorption reactions that involve exchangeable Al. Soil Sci. 90, N 1, p. 1-7.

110. DELAS, J. et aut. 1960. Etude par dilution isotopique du cuivre incorporé dans les depuis 70 ans. Compte rend. Acad. sci. 25, N 23, pp. 3867-79 Bibliog. 3 refs.

111. DOMMERQUES, Y. 1960. La notion de coefficient de minéralisation du carbone dans les soles. Agron. Trop. 15, N 1, p. 54-60.

112. Evaluation of laboratory indexes of absorption of soil phosphorus by plants. II. Plant and Soil. 13, n 1, p. 28-38.

113. HEALEY, J. J. 1960. Potassium in the soil. Beter Crops. 44, pp. 10-13.

114. HOGG, D. E. 1960. Magnesium losses from Horotin sandy loam following application of potassium chloride. N. Z. J. agric. Bes. 3, pp. 377-83.

115. HOSODA, K., H. TAKATA. 1960. Studies on the colloid chemical behavior of black soil in Japan. 3. Trans. Tottori Soc. Agr. Sci. N. 12, pp. 77-82.

116. HUDSON, A. W. 1960. Sulphur and its effect on soil acidity. N. Z. J. Agric. 101, N. 3, pp. 283-84.

117. MOFFATT, J. S., M. RADLEY. 1960. Gibberellic acid. XI. The growthpromoting activities of some functional derivatives of gibberellic acid. J. Sci. Food and Agric. II, N 7, pp. 386-90.

118. MOUSTAFA, A. E. H., A. I. SHABASI. 1959. The effect of gypsum and gypsum plus organic matter on the chemical and physical properties of the black alkaline soils. in Egypt. Egypt Ministry Agr. Tech. Bull. N 286, 47 pp. Ref: Chem. Abstr. N. 5, pp. 4986.

119. OLSEN, S. R. and oth. 1960. Soil properties affecting the solubility of calcium phosphates. Soil Sci. 90, N 1, pp. 44-50 Bibliog. pp. 41-50.

120. PAWLIK, A. 1960. Spektralphotometrische Untersuchungen über Dicyandiamid im Boden. Z. Pflanzenernähr., Düng., Bodenkunde, 89(134):(2/3):181-87.

121. PRATT, P. F., G. R. BRADFORD. 1960. Determination of exchangeable cations in soils with the Beckman Model B frame spectrophotometer. Soil Sci. 89, N 6, pp. 342-346.

122. RECVE, R. and oth. 1960. The laboratory examination of soils from the lower Burdekin Valley, North Queensland. CSIRO Dir. Soil divl. Rep. 7/59, 98 pp. Ref.: Soils and Fertilizers, No. 5, pp. 2060.

123. SCHLÜTTER, N. 1960. Neuere Erkenntsnsse der Huminsäurenforschung. Landwirtsch. Foresch.

124. SCHNITSER, M., J. R. WRIGHT. 1960. Nitric acid oxidation of the organic matter of podzol. Soil Sci. Soc. America Proc. 24, N 4, pp. 273-76.

125. SCOTT, A. D., M. G. REED. 1960. Determination of the precipitated potassium in sodium tetraphenylboron — micaceous mineral systems. Soil Sci. Soc. America Proc. 24, N 24, 4 p. 326-27.

126. STÄHLBERG, S. 1960. Studies on the release of bases from minerals and soils. 3. The release of potassium by boiling normal hydrochloric acid. 4. The release of calcium and magnesium by boiling normal Hydrochloric acid. Acta Agric. Scand. N. 23, p. 185-225 Bibliog. 25 and 19 ref.

127. TUCKER, B. M. 1960. Measurement of the ion-exchange properties of soils. Melbourne, 40. pp.

128. UCHARA, G., M. M. MORLAND. 1960. Activity measurements in water and

clay-water systems with tertiary electrodes. Soil Sci. Soc. America Proc. 24, N 4, pp. 261-64.

129. UNGER, H. 1960. Ein Beitrag zur Methodik der Bodentemperatur und Bodenreaktionmessung. Z. Landw. versuchs. Untersuch. 6, Ht. 3, S. 235-43 Bibliog. II Ref.

130. WRIGHT, B. C., M. PEECH. 1960. Characterization of phosphate reaction products in acid soils by the application of solubility criteria. Soil Sci. 90, No. 1, pp. 32-43. Bibliog. pp. 42-43.

BIOLOGY AND MICROBIOLOGY OF SOILS

131. GAMBASHIDZE, K. K. Microbiological processes in sod-podzolic soils of the Adzhamet plain in relation to the method of tillage. Soobshch. AN Gruz-SSR. 25(2):185-192. Bibliog. 9 refs.

132. GEL'TSER, YU. G. 1960. Method of direct observation of soil amoebae in the rhizosphere of plants. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 4:195-200. Bibliog. pp. 199-200.

133. DARZNIYEK, YU. O. 1960. Influence of cotton on the development of the Azotobacter in soil. Mikrobiologiya. 29(6):868-874. Bibliog. pp. 873-874.

134. KARAGUYSHIYEVA, D. 1960. Principles of the development of the Azotobacter in certain soils of Kazakhstan. Author's summary of her dissertation for a candidate's degree in biological sciences. (Kazakh. gos. un-t). Alma-Ata. 21 pp.

135. PANOSYAN, A. K., R. SH. ARUTYNYAN, and A. V. MARTAVINA. 1960. Influence of metabolites of certain soil microorganisms on the growth and development of plants. Dokl. (AN ArmSSR). 31(2):117-121. Bibliog. 7 refs.

136. SABEL'NIKOVA, V. I. 1960. Dependence of the development of the Azotobacter on the presence of $CaCO_3$ in the soils of Moldavia. Izv. Moldav. filiala AN SSSR. No. 6:75-80. Summary in Moldavian.

137. BECK, T. R. RÖSCHENTHALER. 1960. Strahlembiologie der Mikroorganismen. Eine Literaturansammlung über den neusten Stand der Beeinflussung von Mikroorganismen durch ionisierende Stranhlen. Bayer landw. Jb. 37, 2, 82 S.

138. CAIN, R. B. 1960. Some beneficial effects of soil microorganisms, Gardeners Chronicle. 148, N. 17, p. 429.

139. CASIDA, L. E. 1960. Oxidation of phosphite by soil microorganisms. Bact. Proc. 28, ref.: Soils and Fertilizers, No. 4, pp. 1692.

140. DOMMERGUES, Y. 1960. Un exemple d'utilisation des techniques biologiques dans la caracterisation des types pédologiques. Agr. Trop. 15, N 1, pp. 61-72.

141. ISWAREN, V. 1960. Influence of combined nitrogen on fixation of nitrogen by Azotobacter. Proc. Indian Acad. Sci. Sect. B. 51, N 1, pp. 32-36.

142. FRERCKE, W., D. PUFFE. 1960, Über Keimzahlbestimmungen. Zellulosezersetzung und die Stickstoffwirkung auf den Zersetzungsvergang in Moorböden und Sandmischkulturen unterschiedlicher Aufkalkung. Z. Pflanzenernähr. Düng., Bodenkunde, 89 (134), Ht. 1 S. 27-42. Bibliog. 42 Ref.

143. GYLLENBERG, H., R. HACKMEN. 1960. Effect of growth rate on the production of vitamin B^{12}-active substances by soil bacteria. Experiments with a strain of Pseudomonas. Acta Agric. Scand. N 23, p. 177-84. Bibliog. 12 refs.

144. HEPPLE, S. 1960. The movement of fungal spores in soil. Trans. Mycol. Soc. 43, N 1, 73-79.

145. LOUB, W. 1960. Die mikrobiologische Charakterisierung von Bodentypen. Bodenkultur, II, S. 38-70.

146. MARKOVITZ, A. 1960. Polysaccharide composition and synthesis in bacteria isolated from soil. Bact. Proc. 60 pp. 31.

147. MENZIES, J. D. 1960. Continuous-flow dilution of soil suspensions for microbial assay. Canadian J. Microbiology. 6, N 5, pp. 583-90.

148. MITCHELL, R., M. ALEXANDER. 1960. Microbiological changes in flooded soils. Summary. Bact. Proc. 60 pp. 28.

149. NETZSCH-LEHNER, A., W. NOWAK. 1960. Verändert Bebrütung den Bakteriengehalt von Böden. Z. Pflanzenernähr., Düng., Bodenkunde. 90(135): (1/2):146-93.

150. ROUATT, J. W., H. KATZNELSON. 1960. Influence of light on bacterial flora of roots. Nature. 186, N 4725, pp. 659-60.

151. SAKAI, H. 1960. Studies on nitrification in soils. Pt. 9. The interrelationships between nitrifying organisms and nitrate reducing organisms. Res. Bull. Hokkaido nat. agric. Exp. Sta. 75, p. 60-67. Ref.: Soils and Fertilizers, N 5 pp. 2091.

152. SUNDARO, RAO, W. V. B., S. P. MATHUR. 1960. The use of silica gel for the enumeration and isolation of Azotobacter in soil. Proc. Indian Acad. Sci. 518, pp. 191-94.

153. TSUMURA, N., T. SATO. 1960. Conversion of D-glucose by a strain of soil bacteria.

Bull. Agric. Chem. Soc. Japan. 24, N 3, pp. 326-27.

SOIL FERTILITY, FERTILIZER, AND TILLAGE

154. ANDREYEVA, YE. I. and L. T. ANDRIANOV. 1960. Influence of perennial grasses on the fertility of soil and the forage balance. Zemledeliye. No. 12:40-43.

155. BAYTKANOV, K. A. 1960. Dynamics of the conditions of fertility of southern calcareous chernozems in the Akmolinsk Oblast' after the reclamation of virgin land. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Kazakh. gos. s.-kh. in-t, kafedra pochvovedeniya). Alma-Ata. 28 pp.

156. BAT'KAYEV, ZH. 1960. Influence of alfalfa and fertilizers on the chemical properties of dark sierozems. Tr. VNII khlopkovodstva. No. 1:58-65. Bibliog. pp. 65.

157. BELOUSOV, M. A. and A. L. TOROPKINA. Simple methods of agricultural-chemical control of soil conditions and the nutrition of cotton. Ibid. pp. 76-82. Bibliog. 10 refs.

158. BUGUSHEVSKAYA, V. and M. KATS-KATSAC. 1961. Fertilization and liming of soils in Poland. Zemledeliye. No. 1:75-80.

159. VLASYUK, P. A., Z. M. KLIMOVITSKAYA, and K. L. VIZIR. 1960. Role of the root system in the migration and transformation of manganese in plants. Izv. AN SSSR. Ser. biol. No. 6:865-873. Bibliog. pp. 873.

160. GULYAKIN, I. V. and YE. V. YUDINTSEVA. Uptake by plants and accumulation in the yield of certain radioactive products of fission. Ibid. pp. 874-885. Bibliog. p. 884.

161. GULYAKIN, I. V., YE. V. YUDINTSEVA, and E. M. LEVINA. 1960. Accumulation of Sr^{90} in the yield of agricultural crops in relation to its concentration in the soil. Izv. Timiryazevskoy s.-kh. akad. No. 6: 7-22.

162. GUSEYNOV, R. K. 1960. Conditions for increasing the effectiveness of phosphorous fertilizers. Baku, Izd. AN AzerbSSR. p. 214, with illustr. Bibliog. pp. 294-313.

163. IGNATENKO, I. I. 1960. Main tillage system of Azov chernozems in Kuban'. Zemledeliye. No. 12:52-55.

164. KRUPENIKOV, I. A. and I. I. SHILIKINA. 1960. Yield of agricultural crops on various chernozem subgroups. Izv. Moldav. filiala AN SSSR. No. 6:25-30. Bibliog. 5 refs. Summary in Moldavian.

165. LYSENKO, T. D. 1960. Soil nutrition of plants — a basis problem in agricultural science. Moscow, Izd. lit. na inostr. yaz. 147 pp. In Spanish.

166. MUSABEKOVA, E. S. 1960. Agricultural chemical characterization of the main soil groups in the Shirvan steppe. Baku, Izd. AN AzerbSSR. 82 pp. with map. Bibliog. pp. 80-81. In Azerbaydzhan.

167. NIKOLAYENKO, G. S. 1960. Problems of the economical evaluation of land in Kazakhstan. Vestn. s.-kh. nauki (Alma-Ata). No. 7:54-64. Summary in Kazakh.

168. Plant nutrition and the use of fertilizers. (Collection of articles under the editorship of N. I. Sinyagin). 1960. Tr. Vsesoyuzn. n.-i. in-ta udobr. i agropochvovedeniya. No. 36: 195, with illustr.

169. Fertility of soils and their fertilization. 1960. (Ukr. n.-i. in-t zemledeliya. Nauchn. tr. 10 [1]). Kiev. Izd. Ukr. akad. s.-kh. nauk. 118 pp. In Ukrainian with a summary in Russian.

170. SAIDOV, D. K. 1960. Influence of the carbonate-magnesium salinization of soils on the anatomic-morphological and physiological characteristics of cotton and corn. Author's summary of his dissertation for a degree in biological sciences. (Uzbek. s.-kh. in-t). Tashkent. 26 pp.

171. SARISHVILI, I. F., A. D. MENAGARISHVILI, and I. A. NAKAIDZE. 1960. Agricultural chemistry. Instructions for agricultural institutions of higher learning. Tbilisi, Izd. Gruz. s.-kh. in-ta. 414 pp. with illustr. Bibliog. 17 refs.

172. SLAVINA, T. P. 1960. Influence of soil moisture on the mobilization of nitrogen. Nauchn. dokl. vyssh. shkoly. Biol. nauki. No. 4:221-226.

173. Manual on mineral fertilizers. Theory and practical application. 1960. Edited by M. V. Katalymova (chief editor) et al. Moscow, Sel'khozgiz. 551 pp. with maps. Bibliog. pp. 543-545.

174. TRUSH, M. M. 1960. Ways of increasing the effectiveness of fertilizers under conditions of the southern subzone of the Northwestern RSFSR. Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Mosk. s.-kh. akad. im. Timiryazeva). Moscow. 18 pp.

175. TSYGANOV, M. S. 1960. Ways of increasing the fertility of soils in the Voronezh Oblast'. Vornezh, Kn. izd. 82 pp. with illustr. Bibliog. 26 refs.

176. CHAGIN, V. P. 1960. Theory of soil tillage in arid regions. Zemledeliya. No. 12:74-80.

177. BOCRUIU, I. 1960. Ingrasarea rationala a griului si prumbului pe solurile din Transilvania. Probleme Agricole. N IO

pp. 41-51.

178. BOSWIMKLE, E. 1960. The application of phosphate fertilizer on different crop rotations in Kenya. East Afric. Agr. a Forest J. 26, NI, p. 65-67. Bibliog. 3 refs.

179. CACKETT, K. E. 1960. A manurial trial on granite sand at Matopos Research Station. Rhod. agric. J. 57, pp. 111-15. Ref.: Soils and Fertilizers, N 5 pp. 2050.

180. ECKERT, R., A. T. BLEAK. 1960. The nutrient status of four mountain Rangeland soils in Western Nevada and Eastern California. J. Range Manag. 2 13, N 4, p. 184-188. Bibliog. 14 refs.

181. Effect of soil management practices on infiltration rates. Soil Sci. 89, N 6, pp. 338-41.

182. GARDNER, W. R. 1960. Dynamic aspects of water availability to plants. Soil Sci. N 2, pp. 63-73.

183. GÖTZ, W. 1960. Um den Wertverlust des Bodens. "Mitt. Dtsch. Landwirtschafts – Ges." 75, Ht. 33, S. 1020-23.

184. HUTCHISON, J. E. 1960. Texas' intensified soil fertility program. Texas agricultural progress, NI, pp. 3-4.

185. LINSER, H., K. KAINDL. 1960. Isotope in der Landwirtschaft. Hamberg-Berlin, 442 S. Bibliog. S. 391-435.

186. MOOMAW, J. C., M. TAKAHASHI. 1960. Vegetation on gibbsitic soils in Hawaii. J. Arnold Arboretum Harvard university, 41, N 4, pp. 391-413. Bibliog. pp. 403-04.

187. PRICE, O. T. W. 1960. Nitrogen fertilizers in British farming. Agricultura, 47, N 6, pp. 289-93.

188. SEIBERTH, W. 1960. Phosphatversorgung der Bodenfruchtbarkeit. "Mitteil. Dtsch. Landwirtsch. Gesellsch." 75, Ht 33, S. 1019-20.

189. SPAIN, J. M., J. B. LILJEDAHL. 1960. Vertical mulching. World Crops, N 11, pp. 419-21.

190. TERPSTRA, A. 1960. Soil fertility and destruction in modern culture. CMC Melk. 15, N 24, pp. 384-88.

191. Über die Aufgaben der Bearbeitung schwerer Böden. Mitteil. Dtsch. Landwirtsch. -Gesellsch. 75, Ht. 33, S. 1017-18.

192. WALKER, T. W. 1960. Uptake of ions by plants growing in soil. Soil Sci. 89, N 6, pp. 328-32. Bibliog. pp. 331-32.

193. WELLS, N., W. M. H. SAUNDERS. 1960. Soil studies using sweet vernal to assess element availability. 4. Phosphorus N. Z. J. agric. Res. 3, pp. 279-99.

194. WITTICH. 1960. Bolenbearbeitung. Forstztschr. N 42, S. 601.

SOIL MELIORATION

195. AKHUNDOV, A. K. and K. G. TEYMUROV. 1960. Periods for leaching soils salinized with sodium sulfate salts. Dokl. (AN AzerbSSR). Vol. 16:977-981. Summary in Azerbaydzhan.

196. ANISIMOV, V. A. and G. M. ZYULIKOV. 1960. Planning and calculation of closed irrigation systems. Moscow, Izd. M-va s. kh. SSSR. 204 pp. with Illustr. Bibliog. 76 refs.

197. BALYABO, N. K. 1961. Irrigation of meadow-bog soils with ground water. Khlopkovodstvo. No. 1:52-56.

198. VALIYEV, V. 1960. Melioration of solonetzic soils in the Turkestan steppe Tr. VNII khlopkovodstva. No. 1:50-57.

199. ZHIVTONOG, I. S. 1960. Methods of desalinizing flood-plain lands when growing rice. (Taking the Southern Buga River flood plain as an example). Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Ukr. akad. s.-kh. n.). Kiev. 29 pp.

200. KALABUGIN, A. YA. and S. I. MURASHEV. 1960. Agricultural water supply and melioration. (Textbook for agricultural institutions of higher learning). Moscow, Sel'khozgiz. 344 pp. with illustr. and maps.

201. KOLPAKOV, V. V. 1960. Influence of moisture supply and leaching irrigation on the salt regime and the leaching ability of soils and soil materials in the Sivash region. Izv. Timiryazevskoy s.-kh. akad. No. 6:113-128. Bibliog. 5 refs.

202. KOSTYAKOV, A. N. 1960. Fundamentals of melioration. 6th rev. and suppl. ed. (Textbook for agricultural institutions of higher learning). Moscow, Sel'khozgiz. 622 pp. with illustr.

203. MIRKIN, S. L. 1960. Water melioration in the USSR and ways of developing it. Moscow, Izd. AN SSSR. 283 pp. with illustr. and maps. (AN SSSR, SOPS, Issled. po voprosam razvitiya i razmeshcheniya s. kh. SSSR). Bibliog. pp. 273-281.

204. SAUKA, O. K. 1960. Drainage regime in excessively wet mineral soils. Tr. Latv. s.-kh. akad. No. 9:405-415. Bibliog. 10 refs.

205. FRY, A. W., J. K. DAVIS. 1960. Simple and accurate device for sprinkler irrigation flow measurements. California Agricul. 14 N. 3, pp. 13.

206. MISÚT, O. 1960. niektroych osobitnistiach

rezimu spodnych vod Zàhorskej niziny. Vodohospodarsky casopis, 8(3)225-34 Bibliog. 3 refs.

207. REEVE, R. C., C. A. BOWER. 1960. Use of high-salt waters as a flocculan and source of divalent cations for reclaiming sodic soils. Soil Sci. 90, N 2, pp. 139-144. Bibliog. pp. 143-44.

SOIL EROSION AND ITS CONTROL

208. BLAGONRAVOV, P., P. SHCHERBAKOV, A. VOLOSHIN, et al. 1960. Let us control erosion effectively in vinyards on southern banks. Vinogradarstvo is sadovodstvo Kryma. No. 11:36-40.

209. BOGOYARVLENSKIY, S. A., B. V. LANDYSHEV, and A. S. FAT'YANOV. 1960. Soil erosion and its control. Gor'kiy, Kn. izd. 57 pp. with illustr. and maps.

210. GORINSKIY, V. N. 1960. Experimental control of soil erosion in Thuringia. (Material taken from "Deutsche Landwirtschaft" [German Democratic Republic], No. 2, 1958). Zemledeliye. No. 12:87-88.

211. DIZENGOF, G. I. and L. F. DIZENGOF. 1960. Reclamation of mountain slopes by leveling the surface. S. kh. Sev. Kavkaza. No. 12:49-53.

212. DUKHNOV, V. K. 1960. Experimental reclamation of eroded lands. Zemledeliye. No. 12:46-51.

213. ZASLAVSKIY, M. N. 1960. Soil erosion control in Moldavia — a problem of great importance to national economy. Okhrana prirody Moldavii. No. 1:34-46.

214. ZASLAVSKIY, M. N. System of erosion control measures during the reclamation of slopes for perennial plantings in Moldavia. Ibid. pp. 47-54. Bibliog. 15 refs.

215. KLIMOV, A. I. 1960. Processes of soil water erosion, scouring, and wind erosion in the Chita Oblast'. Uch. zap. (Chitinsk. ped. in-t). No. 6:347-352.

216. KOCHERGA, F. K. 1960. Measures for the control of erosion and flash floods in Central Asia. Vestn. s.-kh. nauki. No. 11:91-99.

217. OLIFAROV, A. N. 1960. Protection of soils from erosion in the Chinese People's Republic. Vestn. s.-kh. nauki. No. 11:143-148. Bibliog. 10 refs.

218. SADRIDDINOV, A. 1960. Grain crops on eroded sierozems and cinnamon-brown calcareous soils. S. kh. Tadzhikistana. No. 12:35-38.

219. FEDOTOV, V. S. 1960. Complex of erosion control measures during the reclamation of slopes for gardens and vinyards. Izv. Moldav. filiala AN SSSR. No. 6:41-52. Bibliog. 18 refs. Summary in Moldavian.

220. KHOLUPYAK, K. L. 1960. Development of concrete recommendations for erosion control in the Ukrainian SSSR. Vestn. s.-kh. nauki. No. 11:84-90.

221. CHÈNG ZI-CHÈNG. 1960. Comparison of erosion processes in the loess region of the Yangtze River and in the Central Russian plateau. Author's summary of his dissertation for a candidate's degree in geographical sciences. (Mosk. gos. un-t). Moscow. 22 pp.

222. YAKUBOV, T. F. 1960. The wind erosion of soil can be prevented. Sovkhoz. proizvodstvo. No. 11:39-41.

223. AGRAWAL, S. C., N. D. REGE. 1960. Controlling soil loss through proper cover. Indian Forester, 86, N 7, pp. 440-44.

224. CAMERON, D. C. 1960. Legumes for soil conservation. World Crops. No. 11, pp. 429-30.

225. HARA, M. and oth. 1960. Studies of soil erosion in the denuded forest lands. 2. Tottori Soc. Agric. Sci. Trans. N 12, pp. 122-31.

226. WISCHMEIER, W. H. 1960. Cropping-management factor evaluations for a universary soil-loss equation. Soil Sci. America. Proc. 24, No. 4, pp. 322-26.

FOREST SOIL SCIENCE

227. BUSH, M. 1960. Sand dunes of Latvia and their afforestation. Riga, Latgosizdat. 143 pp. with il. Bibliog. 96 refs. In Latvian.

228. DMITRIYEV, I. D. 1960. Application of aerial photographic surveys for the hydrological melioration of forests. Tr. Leningr. lesotekhn. akad. No. 93: 96-105.

229. KONDRASHOV, B. V. 1961. Forest shelterbelts and soil water supply. Zemledeliye. No. 1:43-47.

230. KRUPENIKOV, I. A. 1960. Soil in the forests of southern Moldavia in relation to their conservation and reconstruction. Okhrana prirody Moldavii. No. 1:70-76. Bibliog. 14 refs.

231. MYAKOTINA, G. V. 1960. Investigation of various methods of soil tillage for promoting forest regeneration in clean-cut areas of the Leningrad Oblast', Author's summary of his dissertation for a candidate's degree in agricultural sciences. (Leningr. lesotekhn. akad.). Leningrad. 28 pp.

232. Soils and forest shelterbelts in the southeastern European USSR. (Vsesoyuzn. n.-i. in-t agrolesomelioratsii "VNIALMI." Sb. rabot. No. 31). Moscow-Leningrad, Goslesbumizdat. 224 pp. with illustration.

233. RUBTSOV, N. I. 1960. Problem of the establishment of forest shelterbelts in the area of the water reservoir of the Gor'kiy hydroelectric power station. (Nauchn. -tekh. ob-vo lesnoy prom.). Gor'kiy. 44 pp.

234. TRAVEN', F. I. 1960. Forest shelterbelts — a reliable means of soil erosion control. From the experience gained in growing forest belts in the sovkhozes of the Northern Caucasus. Sovkhoz. proizvodstvo. No. 12:39-43.

235. YAROSLAVTSEV, G. D. 1960. Growth of roots (of woody plants) and soil maintenance on the southern shore of the Crimea. Tr. Nikitskogo botan. sada. Vol. 32:67-79. Bibliog. pp. 78-79.

236. BHIMAYA, C. P., R. N. KAUL. 1960. Some afforestation problems and research needs in relation to erosion control in arid and semi-arid parts of Rajasthan. Indian Forester, 86, N8, pp. 453-68. Bibliog. 7 refs.

237. SIMEK, M. 1960. Odvadnováni tesnich pud. Lecnická práce, N_8'11:509-511.

MISCELLANEOUS, HISTORY OF SOIL SCIENCE

238. BELOVA, N. I. and I. S. KAURICHEV. 1960. For the thorough study of philosophical problems of soil science. (In reference to the article by I. L. Yurova "Problem of contradictions in the process of soil formation" in "Nauchn. dokl. vyssh. shkoly. Filosof. nauki," No. 3, 1958). Nauchn. dokl. vyssh. shkoly. Filosof. nauki. No. 4:111-115.

239. BELOKOPYTOV, I. YE. 1960. M. V. Lomonosov on bogs and peat. Torf. prom. No. 8:25-27. Bibliog. 8 refs.

240. Problems of farming, plant growing, and soil science. (Collection of articles), 1959. (Permskiy gos. s. -kh. in-t. Tr. 17 [2]). Perm'. 253 pp. with illustr.

241. Problems of soil science, fertilization, and plant growing. 1960. (Litov. n. -i. in-t zemledeliya. Inform. byul. No. 3). Vilnus, Gaz. -zh. izd. 46 pp.

242. DMITRIYEVA, N. V. and Z. G. MELEZHNIKOV. 1960. Preparation of portable soil monoliths. Izv. Moldav. filiala AN SSSR. No. 6:81-84. Summary in Moldavian.

243. DMITRIY NIKOLAYEVICH PRYANISHNIKOV. 1960. (Introduction by A. V. Peterburgskiy). (Scientists of the Timiryazev Academy). Moscow. 124 pp. with illustr. and maps.

244. MEDVEDEV, A. G., I. P. BULGAKOV. and YU. I. GAVRILENKO. 1960. Instructions for soil investigations in kolkhozes and sovkhozes of the Belorussian SSR. (Approved by the inspection of agriculture of the Ministry of Agriculture of the Belorussian SSSR). Chief editor, I. S. Lupinovich, Izd. Akad. s. kh. nauk BSSR. Minsk. 176 pp. Bibliog. 33 refs.

245. ALEKSANDROVA, L. N., I. N. ANTIPOV-KARATAYEV, I. F. GARKUSHA, et al. 1960. Soil science. Edited by K. P. Gorshenin. (Textbook for agricultural instructions of higher learning). Kiev, Gossel'khozizdat USSR. 423 pp. with illustr. and maps. Bibliog. pp. 408-412. In Ukrainian.

246. SKUYANS and G. MEZHAS. 1960. Soil investigation in the field and in the laboratory. Riga, Latgosizdat. 245 pp. with il. and maps. Bibliog. p. 242, In Latvian.

247. BERGMANN, W. 1960. Aufgaben. Zeil und Grenzen der Bodenuntersuchungsmetoden. Dtsch. Landwirtsch. Jg. II, Ht. I, S. 32-35.

248. FLAIG, N., H. KEPPEL. 1960. Atomphysik im Dienste der Bodenforschung. Mitteil. Dtsch. Landwirtsch. Gesell. 75, Mt. 33, S. 1023-25.

249. HUTCHEON, W. L. 1960. The application of information from soil surveys. Agric. Inst. Rev. 15 N 2, pp. 51-53.

250. LINVILLE, R. A., O. L. MUSGRAVE. 1960. How to sample soil for testing. Ohio Ag. Exp. Bull. 388, pp. 1-8.

251. RIPLEY, P. O., H. J. ATKINSON. 1960. Organization and major lines of soil research in Canada. Agric. Inst. Riev. 15, N 2, pp. 54-56.

252. TAYLOR, J. K. 1960. Soils J. Austral. Inst. Agric. Sci. 26, N 2, pp. 118-33.

AIBS Russian Monograph Translations

The AIBS is in the process of expanding its Russian Translations Program extensively. Funds to subsidize translation and publication of important Russian literature in biology have been obtained from the National Science Foundation, as part of a larger program to encourage the exchange of scientific information between the two countries. The following monographs have been published:

Origins of Angiospermous Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
68 pp. [13 illustrations] 8½ x 10¾. $3.00, individuals and industrial libraries (U.S. & Canada); $2.00, AIBS members and all other libraries; $.50 additional, foreign.

Essays on the Evolutionary Morphology of Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
144 pp. [32 illustrations] 8½ x 10¾. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Problems in the Classification of Antagonists of Actinomycetes. *By G. F. Gause*
Edited by David Gottlieb. Translated by Fritz Danga
165 pp. [18 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Arachnida. Vol. IV, No. 2. Fauna of the U.S.S.R. *By B. I. Pomerantzev*
Edited by George Anastos. Translated by Alena Elbl.
199 pp. [638 illustrations] 7 x 10. $10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Arachnoidea. Vol. VI, No. 1. Fauna of the U.S.S.R. *By A. A. Zachvatkin*
Translated and edited by A. Ratcliffe and A. M. Hughes
567 pp. [705 illustrations] 7 x 10. $10.00, individuals and industrial libraries; (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Marine Biology. Trudy Institute of Oceanology. Vol. XX. *Edited by B. N. Nikitin*
302 pp. [66 illustrations] 8½ x 10¾. $10.00, individuals and industrial libraries; (U.S. & Canada; $7.50, AIBS members and all other libraries; $1.00, additional, foreign.

Plants and Xrays. *By L. P. Breslavets*
Editor of English Edition: Arnold H. Sparrow
115 pp. [26 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Wintering of Plants. *By I. M. Vasil'yev*
Editor of English edition: Jacob Levitt.
$9.00, individuals and industrial libraries (U.S. & Canada); $8.00, AIBS members and all other libraries; $.50, additional, foreign.

Monogenetic Trematodes, Their Systematics and Phylogeny. *By Boris E. Bychowsky.*
Editor of English edition: William J. Hargis, Jr.
$10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $.50, additional, foreign.

For orders and a FREE copy of our Publications Catalog listing all AIBS Publications, write to:

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
2000 P Street, N.W. Washington 6, D. C.

AGRONOMY SEMINAR
305 DAVENPORT HALL

TRANSLATIONS OF RUSSIAN BIOLOGICAL JOURNALS

The American Institute of Biological Sciences, under a grant from the National Science Foundation, is currently translating and publishing seven Russian research journals in biology.

DOKLADY: BIOLOGICAL SCIENCES SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$20.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$15.00 per year, AIBS members and all other libraries
$2.50 additional to each price, foreign
$4.00 each, single copies

DOKLADY: BOTANICAL SCIENCES SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$7.50 per year, individuals and industrial libraries (U.S.A. & Canada
$5.75 per year, AIBS members and all other libraries
$1.50 additional to each price, foreign
$1.50 each, single copies

DOKLADY: BIOCHEMISTRY SECTION

6 issues per year. First issues published: 1957, Vols. 112-117. Current issues published 1961, Vols. 136-141.

Subscriptions:

$15.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$10.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$4.50 each, single copies

PLANT PHYSIOLOGY • FIIZIOLOGIYA RASTENIY

6 issues per year. First issues published: 1957. Vol. 4, Nos. 1-6. Current issues published: 1961, Vol. 8, Nos. 1-6.

Subscriptions:

$15.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$11.00 per year, AIBS members and all other libraries
$2.00 additional to each price, foreign
$3.00 each, single copies

SOVIET SOIL SCIENCE • POCHVOVEDENIYE

12 issues per year. First issues published: 1958. Current issues published: Jan.-Dec., 1960.

Subscriptions:

$20.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$15.00 per year, AIBS members and all other libraries
$2.50 additional to each price, foreign
$4.00 each, single copies

MICROBIOLOGY • MIKROBIOLOGIYA

6 issues per year. First issues published: 1957, Vol. 26, Nos. 1-6. Current issues published: 1961, Vol. 30, Nos. 1-6.

Subscriptions:

$40.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$20.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$4.50 each, single copies

ENTOMOLOGICAL REVIEW
ENTOMOLOGICHESKOYE OBOZRENIYE

4 issues per year. First issues published: 1958. Current issues published: 1961, Vol. 40, Nos. 1-4.

Subscriptions:

$25.00 per year, individuals and industrial libraries (U.S.A. & Canada)
$12.00 per year, AIBS members and all other libraries
$3.00 additional to each price, foreign
$7.50 each, single copies

Order from:

AMERICAN INSTITUTE OF BIOLOGICAL SCIENCES
2000 P Street, N.W. Washington 6, D. C.